VISUAL SUMMARIES AUGMENTING MEMORY RECALL OF REPETITIVE ACTIONS

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VISUAL SUMMARIES AUGMENTING MEMORY RECALL OF REPETITIVE ACTIONS

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For my husband and my father.

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GLOSSARY

activity Term from activity theory delimited as sequence of actions or tasks., p. 1.

augmentative technology Norman's term for "voluntary, friendly, and cooperative. Use it or ignore it, as you wish" providers of "sensible suggestions, but because they are optional, they do not disrupt. Their occasional success suffice to keep us content with their operation." [86] He cited recommender systems and the Cook's Collage as examples., p. 23.

cognitive failure "Cognitive error occurring during the performance of a task, that is normally well within the ability of the person carrying it out. An 'unforced error' of cognitive origin." [73], p. 1.

ecological validity Neisser's term that applies to "natural conditions: the circumstances in which it occurs, the forms it takes, the variables on which it depends, the differences between individuals in their uses of the past." [83], p. 18.

environmental cue External, physical *things* that are around us in the environment that play an essential role in acting as triggers and placeholders to prompt further action [29]., p. 2.

everyday "Naturalistic or realistic, or related to everyday experience, not necessarily frequent or common. Everyday represents some point along a spectrum that ranges from elaborately controlled artificial to spontaneously occurring in nature."[114], p. 1.

ingredient error My term in defining the physical inaccuracy of an ingredient addition by comparing the incorrect counts from the cook against the correct number of counts as listed by the assigned recipe. This also includes missed ingredients. This term does not imply any causality from memory slip, cognitive failure, cooking mistake, etc., p. 100.

memory aid From memory literature to comprise of anything and everything that aids any type of memory including internal aids (e.g., mnemonic, rhyme, story method, mental retracing sequence of events or actions, face-name association) and external aids (e.g., shopping lists, memos, diaries, alarm clocks)., p. 3.

memory cue Small details of an past event or experience that *may* help in recalling and recollecting more details of the memory. Solely used for retrospective memory. [68], p. 3.

memory device My term for an electronic or technological device serving as an external memory aid (e.g., alarm clock). Also known as automated aid [95], p. 3.

memory episode My term to include the situational context (i.e., the physical surroundings of any and all concurrent activities, interview comments from the participant about the experience) before, during, and after each opportunity for a memory slip that differentiates this current instance from another previous incident., p. 1.

memory for action Type of memory targeting the retrospective memory recall of motor information from the physical act of performing. [117] Also known as *memory for activities*, p. 1.

memory introspection paradox Phenomenon that participants who are most likely to make memory errors are also the same ones most likely to forget that such an error took place [43]. Also known as Meta-Memory Paradox, p. 2.

memory slip Hay and Jacoby's term for "a type of action slip that emerges when *habit* dominates *recollection* for a specific event"[40] with Norman's definition of an action slip as "an error in performance that results when an *automatic* basis for responding (e.g., habit) dominates the *intention* to perform a specific behavior" by arguing that "These errors arise in situations that place *habit* and *current intentions* in opposition, each leading to different outcomes.", p. 1.

memory strategies Term used in memory studies that included internal aids (i.e, formal techniques such as mnemonics and story association that required training or practice to use), use of external aids (e.g., writing down notes, asking others to remember, intelligent use of space[61]), and general internal strategies (i.e., "normal memory operation" such as mental retracing of steps). Also known as coping strategy, p. 3.

memory surrogate Wendy's term meaning proxy, representative of memory. I added caveat that a memory surrogate is just *another* memory record (i.e., secondary source) that could also be inaccurate (from wizard of Oz error) and/or inconsistent with user's memory recall (i.e., primary source)., p. 3.

memory trigger *Minimal* detail(s) of an experience that *does* help in recalling having done something [19], in *prompting* further action of tasks within an activity [29]., p. 3.

mistake "A person establishes an intention to act. If the intention is not appropriate, this is a *mistake*. If the action is not what was intended, this is a *slip*.... Mistakes result from the choice of inappropriate goals. A person makes a poor decision, misclassify a situation, or fails to take all the relevant factors into account." [85], p. 98.

non-users My term for individuals who have not experienced cooking with the Cook's Collage or who have not stood in the same physical position of the participating cooks in the Aware Home kitchen to orient their visual perspective of the ingredients shown in the Cook's Collage in the first-person point of view of seeing the same ingredients visible on the kitchen countertops., p. 38.

orthesis Assistance via device that corrects or relieves *weakened* ability by *temporary* compensation (e.g., knee brace, crutches).[70], p. 136.

proof of concept "A short and/or incomplete realization (or synopsis) of a certain method or idea(s) to demonstrate its feasibility, or a demonstration in principle, whose purpose is to verify that some concept or theory is probably capable of exploitation in a useful manner. A related (somewhat synonymous) term is "proof of principle."' [11], p. 28.

prothesis Assistance via device that *enhances* or *enables* ability. (e.g., artificial limb, binoculars). [70], p. 136.

simulation studies "An *everyday task simulation* is a laboratory memory test that bears some resemblance, at least in stimulus content, to an everyday memory experience. There is no requirement that the task exactly emulate in vivo memory activities. Simulated investigations of everyday memory lie along a continuum, with many '*direct-simulation*' tests closely resembling an everyday experience...[and] tend to place the research participant into an everyday contextual framework in which stimulus familiarity and meaningfulness are important for memory because they enable the participant to access *cues* and *strategies* used in the *real world*."[113] She differentiated *indirect* simulation studies as more contrived variations in difficulty level, presentation format, and frequency of stimuli., p. 18.

task Term from activity theory delimiting one step or action that *is done* within an activity. I created the term *task assignment* for this document to disambiguate between the psychology term "task" referring to (series of) action(s) assigned to study participants *to be done* during an experiment., p. 1.

tunnel vision Physically putting one's heads down, focusing on the current task to limit visually one's attention from peripheral distractions, interruptions, and concurrent activity [24]., p. 131.

SUMMARY

Throughout a typical day, people complete myriad tasks and activities such as locking the front door as they run errands around the neighborhood, preparing meals and drinks, taking care of family, pets, plants, and so on. In managing the progress of these everyday activities, people may find themselves needing to recall what they have already done.

In this research, I explored how to design an unobtrusive memory aid that reduces the cost of distraction and general multitasking by fluidly supporting memory recall of repetitive actions. I built the Cook's Collage as one example system that captures close-range photographs of ingredient additions during everyday home cooking to display as an ongoing visual summary of the open-ended activity. I contribute this augmentative technology as a memory aid in contrast to more directive, obtrusive, and yet constrained systems that seek to remove human error through automation and scripted guidance.

I explored how to evaluate memory augmentation by simulating real-life situations of multitasking and interruptions that distracted cooks participating in my experimental study. From examining their behavior and attitudes with and without the Cook's Collage, I demonstrated that 1) Visually summarizing activities by capturing items used within the activity in the same physical surroundings can provide sufficient context in recalling memory for actions, 2) User interaction with accurate memory support that complements and supplements rather than interferes with memory practices, activity constraints, and environmental surroundings can effectively augment memory recall, and 3) Barriers to using provided memory support can include unawareness of memory need and predilection to own memory ability and routine.

CHAPTER I

INTRODUCTION

Throughout a typical day, people complete myriad tasks and activities such as locking the front door as they run errands around the neighborhood, preparing meals and drinks, taking care of family, pets, plants, and so on. In managing the progress of these everyday activities, people may find themselves needing to recall what they have already done, asking

- "Did I lock the front door yet? I am not sure because I was too busy to notice."
- "Did I add sugar to this recipe, or have I absentmindedly added salt instead?"
- "How many teaspoons of sugar have I added? I lost count."
- "I think I already took my medication today, or am I confusing that with yesterday's dosage?"

In these memory examples, each *activity* is comprised of a flexible sequence of *tasks* that require physical *actions*, the actions are *self-performed*, and the tasks' *status* needs to be accurately *recalled* so that the activity on the whole can be completed *correctly*. This type of memory, formally termed *memory for action*, targets the retrospective memory recall of motor information from self-performed actions [32, 117]. A cognitive error occurring during the performance of a task, that is normally well within the ability of the person carrying it out, is defined as a cognitive failure[74]. This thesis examines *memory slip*s (i.e., errors from habits overturning recollection resulting in cognitive failures within memory for action), like the above example *memory episode*s, that cannot be resolved confidently or accurately with common coping strategies or aids.

As various memory studies have shown, recalling memory for actions can fail in everyday life. Diary studies where participants chronicled lapses of attention catalogued a variety of actual occurrences [89]. The "failure/cause recall paradigm" where participants recounted examples of memory failures along with their thoughts on what caused those failures allowed researchers to identify causes of memory failure much in the same way that investigators determine causes of automobile, airplane, and industrial accidents [44]. For example, throwing out an item that was intended to be kept while keeping the item that was intended to be thrown out has been defined as a slip (i.e., description error [84]). These reports demonstrated that memory failures do happen, but they also illustrated limitations of documentation methods (e.g., memory introspection paradox). Laboratory experiments where participants performed specific actions and tasks to recall in next-day return visits showed that younger adults forgot 33% of their memory for actions and older adults forgot 42% [25]. These memory ability curves indicated percentages of memory failures, revealing opportunities for memory improvement. This thesis was motivated from memory study findings that established the potential for memory improvement because memory for actions does fail in everyday life.

There are many external memory aids and internal memory strategies that support memory for actions. People make intelligent use of space by rearranging items to make it easy to track, figure out, remember, and notice the status properties triggering what to do next [61]. These strategies reinforce memory recall by explicitly encoding activity status in the space as environmental cues, thereby making the work status visible. For example, short order cooks at diners have been observed to cluster materials for orders together and leave knives and utensils near the ingredient to be used next, as if to mark their place in their plan [60]. However, memory errors still can happen because the overhead of maintaining timely updates to reflect activity status can be faulty when interrupted, thereby causing confusion of whether or not the rearrangement of markers was prepped before the interruption. As an alternative, people can delegate their memory needs by asking someone else to remember for them, or they can change the nature of the to-be-remembered tasks into to-be-followed tasks from checklists. When memory recall fails, people can recover by mentally retracing their steps or by using rehearsed memory strategies such as mnemonics to jog their memory. This thesis builds upon the effectiveness and limitations of existing external memory aids and known internal memory strategies that support memory for actions.

With the increasing availability of 24/7 monitoring technologies, *memory devices* supporting retrospective recall of actions are becoming more common. Video diaries from the "Satchel" [77] (originally called "Forget-me-not" [64]) system are early examples of using video clips to recall daily transfer of paper documents and file sharing by office workers. More recent examples include the "Personal Audio Loop" [41] that records audio to replay recent conversations and "SenseCam" [47] that records image sequences to stimulate and consolidate recall of autobiographical memory for cognitively impaired patients. Technology provides advantages of automated capture and nominal storage cost, but current technology has difficulty recognizing complex activity and understanding the importance of particular actions. On the other hand, people can quickly and easily recognize and realize the significance of any *memory cue* given appropriate context and attention, but people typically do not pay attention to routine everyday actions as they happen or make mental note in preparing *memory trigger*s. In this thesis, I explore potential synergies of technology's automated capturing capacities and people's effortless recognition of recalled actions to provide effective support of memory for actions. Specifically, I created a display device, "Cook's Collage," visually summarizing recent self-performed actions as a *memory surrogate* to aid in two particular cases of memory for actions in everyday cooking at home.

1.1 *Memory for Actions in Everyday Cooking at Home*

Modern western home kitchens are a publicly open, multipurpose location within the home where house occupants may share the cooking facilities [8]. The kitchen is primarily used for preparing and cooking food, producing a noisy and busy hands-on utility space. The home kitchen also serves as a social common area where house occupants loiter to converse or engage in other group activities, potentially imposing external interruptions and distractions within the cooking area. The kitchen's location connects to other rooms within the house, potentially drawing the cook away from the kitchen to attend to other household responsibilities.

Cooking, the practice or manner of preparing food to make suitable for eating, follows a specific task sequence of a steps from memory (e.g., family recipe), from a written recipe, or be spontaneously haphazard and creatively random. In all cases, cooking includes a definitive beginning and ending state, and at least one cooking step of selection (e.g., choosing an ingredient to add, choosing correct measuring utensil to use), repetition (e.g., adding another scoop of an ingredient, stirring the mixing bowl again), or timing (e.g., simmering sauces, allowing food to cook). These actions are self-performed, and require remembering the progress status to perform correctly. Forgetting cooking steps (e.g. missing or overdoing various ingredients or counts) can yield unpleasant consequences for the produced food or drink.

1.1.1 Everyday Cooking with the Experienced Cook

Because I am investigating cognitive failures defined as cognitive error occurring during the performance of a task, that is normally well within the ability of the person carrying it out, my research targets experienced cooks who are knowledgeable in their everyday cooking tasks. Second, I assume people who enjoy cooking and take pride in giving home-cooked meals to others would consider a cooking memory surrogate helpful because, conversely, I presume a cooking memory surrogate would hold no value for people who would rather purchase ready-made food to avoid cooking all together. Third, I assume experienced cooks who take pride in preparing family recipes that they have perfected over the years. Not being able to recall the cooking progress can cause anxiety or stress for the cook because they *care* about the resulting food quality. They do not need help figuring out what to do, but they may need assistance remembering what they did especially as they age or are distracted. Lastly, I assume memory support in cooking may be useful for amateur cooks and dinner party hosts who can perform the cooking tasks but who may need help managing the process of cooking in addition to synchronizing multiple recipes or timing the arrival of guests. I target cooks who are distractible and forgetful, affecting their attention and memory rather than their cooking knowledge.

1.1.2 Memory for Actions: Recalling and Counting Ingredients

Self-checking one's own cooking progress is problematic for many reasons. First, the lack of visual cues makes determining cooking progress problematic. Consider mixing different ingredients of similar color and texture such as flour, baking soda, baking powder, and sugar. Remembering which ingredients have been added and how much of each has been added can be potentially difficult. All the added ingredients are available and visible, but they are not easily distinguishable. Second, failures of remembering self-performed actions can result from routinized tasks that occur automatically without conscious awareness, or from confusion between already performing an action and intending to perform an action [32]. This problem is apparent to absent-minded and preoccupied cooks in particular but indiscriminately applies to all cooks because preparing food requires focus of attention and memory to remember the completed tasks, monitor and execute current tasks, and anticipate or decide upon subsequent tasks. Lastly, interruptions and multitasking can create memory slips by overloading memory demands. Juggling household chores, reusing limited kitchen utensils, coordinating overlapping cooking times for multiple recipes, and so on increases the activity's difficulty by introducing frequent task switching and simultaneous task monitoring while cooking. Gillie and Broadbent showed that interruptions are more disruptive the more they are similar to the interrupted task, the more complex they are, and the more time they consume [36]. Additionally, memory slips can be caused by general decline of memory abilities from normal healthy aging and worsen from memory illnesses (e.g., Alzheimer, dementia).

1.2 Quick Preview of the Cook's Collage

Figure 1: Screenshot of Cook's Collage

As Figure 1 shows, the Cook's Collage consists of six images (in a 2x3 grid) depicting the six most recent ingredients the cook has already added. The images are camera snapshots capturing the cook adding the ingredients. The yellow numbers annotate the running count for each repeated ingredient. The tortoise and the hare icons along the bottom of the Cook's Collage represent progress indicators that reflect the frequent time delays from the activity recognition system that is monitoring the cook's ingredient additions. Although I will describe fully in Chapter 3, I introduce the Cook's Collage display here to situate the following usage scenario which focuses more on the information flow in the kitchen dynamics than of the visual features of the memory display.

As a technological example of a novel memory surrogate, the Cook's Collage is an information display that visually summarizes recent actions of two specific tasks in cooking recipes to support recall of

- which ingredient has been added; and
- how many times an ingredient has been added.

The following excerpt details a usage scenario of how I intended the Cook's Collage to be used and to be of use. I will return to this usage scenario throughout the thesis to define the underlying concepts that motivated my decisions in designing natural and fluid user interaction, in implementing synergetic and accommodating user-aided activity recognition, and in reporting qualified use cases from experimental study.

1.3 Usage Scenario

Another typical day at 5:30pm in the Johnson's household finds mom returning home with her two kids in tow. While the boys settle in at the dining table with their homework, mom prepares dinner. After peeling and cubing potatoes, she places them into a pot to boil. She seasons several pork chops and places them into the broiler, setting their cooking timer. While waiting for the food to cook, mom retrieves her biscuit recipe card and some ingredients from the pantry. Learning from past experiences that albeit an easy recipe, missing or miscounting an ingredient can result in a ruined batch, mom lines the containers of flour, salt, baking powder, sugar, heavy cream, and half and half beside the mixing bowl. She quickly reads the recipe instructions. However, mom deliberately deviates from the instruction sequence by starting with the baking powder; thereby, ensuring this key ingredient for biscuits is not forgotten this time as it has been before.

Mom rummages the kitchen drawers for the $\frac{1}{2}$ teaspoon utensil, but she finds only the $\frac{1}{4}$ teaspoon utensil. "I guess I can just add twice as much to accommodate the smaller measurement," she muses. While measuring the baking powder amounts, mom's phone chirps with the ring tone of her husband, so she answers the call. He tells her he is on his way home from work and asks if she would like him to stop by the grocery store. Mom reviews the dinner menu with him, satisfied that she is not missing any item. After her phone conversation, she looks into the mixing bowl, puzzled by the seemingly scant amount of baking powder. Then, mom glances at the Cook's Collage for a second opinion. She sees that she had added four counts of baking powder which is the exact number she expected. It takes mom a moment to realize that she is holding the $\frac{1}{4}$ teaspoon instead of her usual $\frac{1}{2}$ teaspoon. She exclaims, "I guess I fell back into my usual routine instead of following through on today's different measurement conversion!" Mom adjusts for the amount of baking powder by adding four more counts. Satisfied with the white mass in the mixing bowl, she chuckles at the Cook's Collage. "Eight counts of baking powder seem excessive, but I know that is the correct amount today."

Mom proceeds with the sugar ingredient snickering, "Nothing better distract me, or this batter will become dessert." As a precaution, she visually inspects the status of the boiling potatoes and her two studious boys. Sensing no signs of imminent interruption, she focuses on adding the sugar amounts quickly. She checks on the boiling potato pot again, giving the Cook's Collage some time to process her recent sugar additions. After which, she confers with the Cook's Collage display to double-check that she had indeed added the amount she intended. With her self-confidence in her counting ability restored, she proceeds with the next ingredient but not before she whimsically adds one extra dash of sugar to satisfy her boys' penchant for sweets.

As with each prior ingredient, mom now selects the salt from her ingredient line-up and places it beside the mixing bowl, using the physical placement to denote it as the current ingredient. As she opens the salt container, her two boys enter the kitchen asking for juice to drink. Nodding, mom takes two glasses from the overhead cabinets and places them on the kitchen counter, making room by moving aside the salt container. She retrieves the juice bottle from the refrigerator and pours into the two glasses to hand to the boys. They return to their seats at the dining table, and mom returns to her mixing bowl to find no ingredient beside the mixing bowl. Realizing that her use of ingredient placement as a progress marker is of no help now, she reviews the recipe to find that it is also of no help because she had not been adhering to the ingredient sequence. "Did I add the salt?" mom wonders as she glances up at the Cook's Collage display. Relieved to resolve the memory slip, she selects the salt again from her ingredient line-up to add it quickly to the mixing bowl before another interruption could interfere.

Mom proceeds to add the required $1\frac{1}{2}$ cups flour with the $\frac{1}{2}$ measuring cup when she hears her son ask, "Mom, I need help with this math problem!" She makes a mental note to herself that her current count is 2 before walking to the dining table. Mom talks her son through the arithmetic problem, encouraging him to count with his fingers, and praising him for his efforts. After helping her son with his counting exercise, she returns to the kitchen only to realize that she too needs help with her counting. She lifts the mixing bowl in a futile attempt to weigh the flour amongst the other white ingredients. With a quick glance at the Cook's Collage, mom resumes her flour count with the final third scoop. She exclaims, "How ironic! At least I do not have to ask for help or watch myself lose count because that would be embarrassing. All I have to do is sneak a peek at the display, and the information is right there."

Mom adds the butter with no distractions, so she takes no notice of the Cook's Collage. Next, she opens both the heavy cream and half and half. She hears her husband opening the front door and the two boys rushing to greet their father. She continues her work by forming a hole in the batter and pouring in the heavy cream. She is kneading the dough with the liquid when her husband enters the kitchen to greet her. Seeing her sticky hands, he asks if he can lend her a hand. She replies, "Good timing! Would you pour me some- oops- I outsmarted myself! I opened both so I could pour each with one hand, but now I confused whether I already added the heavy cream or that I am reminding myself to add the heavy cream next!" Her husband examines the measuring cup saying, "Both liquids look white, both smell milky, and both taste buttery, so I cannot tell either." Then, they glance up at the Cook's Collage to see that she had added the heavy cream. Smiling, her husband offers, "I guess I'll help you pour the half and half since the machine thinks you already added the heavy cream. At this point, its guess is as good as ours."

1.4 Thesis Statements and Contributions

With Cook's Collage as a technological example of a novel memory surrogate that supports recall of memory for actions in cooking at home, this thesis aims to provide insight into two key aspects of memory aid research. One area deals with extenuating biases as barriers to use, and the other addresses the efficacy of visual summaries as memory surrogates. These two goals can be formulated as research questions.

- When presented with a novel memory surrogate, what biases deter people from using provided memory cues?
- Once people do interact with a memory surrogate, which design and implementation features provide effective memory support and which do not?

Through four major rounds of iterative design and evaluation, I gained a better understanding of how to design and implement a memory augmentative system that can be used in real-world situations in which memory slips occur. I have also gained a better understanding of if, when, and how people choose to use memory support. My findings for both research questions can be summarized by the following thesis statements.

- Visually summarizing activities by capturing items used within the activity in the same physical surroundings can provide sufficient context in recalling memory for actions.

- User interaction with accurate memory support that complements and supplements rather than interferes with memory practices, activity constraints, and environmental surroundings can effectively augment memory recall.

- Barriers to using provided memory support can include unawareness of memory need and predilection to own memory ability and routine.

Each of these findings results from evaluating study participants' use and non-use of the Cook's Collage system within a physical laboratory that simulates real-world situations prone to memory slips (e.g., Aware Home kitchen). I provide evidence for these claims from observations, surveys, and interviews throughout the cooking experiments detailed in this thesis. In validating the thesis goals through the design and evaluation of the Cook's Collage system, the research contributions of this thesis include

- Example visual design that supports memory recall of repeated actions;

- Example wizard of Oz simulation that enabled sufficient activity monitoring;

- An experimental method that recreates memory phenomena of *forgetting* recently performed actions;

- Video analysis that illustrates representative uses and non-uses of the Cook's Collage under various conditions; and

- Quantitative accounting of *actual* memory slips and of presumed Cook's Collage usage to compare with *perceived* memory needs and with usage benefits.

The goals and contributions of this thesis can be delineated from many other active memory research efforts. I do not investigate prospective memory that involves the planning, management, and monitoring of intended *to-do* actions in the future that are not yet performed. Rather, I study retrospective memory that entails remembering already performed events in the recent past. The Cook's Collage reviews the user on what recent tasks have already been completed. Consequently, my design does not instruct the user on how to do the next task; thereby restricting the flexibility and creativity in the user's improvised sequencing of the overall activity. For this reason, I build support for memory recall of already completed actions that are independent from assisting the user with intentions for *to-do* actions. The purpose of the technological device is not task support that would be measurable by improved task performance because the Cook's Collage is not intended for novice cooks who are prone to cooking errors such as incorrectly converting measurements of two teaspoons as two one-half teaspoons instead of four one-half teaspoons. Rather, the purpose of the technological device is memory support within any cohesive activity consisting of repeated actions (e.g., cooking). My system, the Cook's Collage, is intended for experienced cooks (i.e., people who can correctly perform a cooking recipe with ease when isolated from memory impairments) who are prone to memory errors. I demonstrate how the Cook's Collage can improve memory performance and memory confidence. The target user group for this thesis is not cognitively impaired patients (e.g., traumatic brain injury patients) who depend on instructional assistance for activities in daily living. Rather, the target user groups of this work are healthy aging adults who require little to no memory assistance for daily activities but are nonetheless prone to everyday memory errors. This thesis focuses on supporting recall of memory for actions in contrast to the many other areas of memory research.

1.5 Overview

In this thesis, I present key insights and breakthroughs from my accumulated lessons learned in creating the Cook's Collage regarding its interaction design, activity monitoring, experimental methods, and use case analyses. In this chapter, I defined the thesis problem and introduced the thesis statements. In Chapter 2, I identify stakeholders and critics to frame the underlying issues to be discussed in this document. In Chapter 3, I detail the Cook's Collage display and motivate design lessons learned through iterative prototyping. In Chapter 4, I detail the software infrastructure and visual interfaces for the Wizard of Oz simulation that enabled interactive user experiences with the Cook's Collage prototype. I motivate implementation lessons learned through honing my monitoring skills as the wizard of Oz operator, and I report my resulting performances regarding recognition accuracy and processing time for participating cooks throughout the Repeated-Use Study. In Chapter 5, I discuss study challenges in evaluating memory augmentation from capturing the phenomenon of forgetting, examining the implicit process of coping strategies, and defining measurements for a successful memory augmentation system. I refer to lessons learned from two preliminary user studies (documented as appendices) and from related work in motivating my method rationale. In Chapter 6, I present the Repeated-Use Study as the main method that evaluated the Cook's Collage with respect to the underlying thesis questions. I report use cases from participants during experimental trials with and without the Cook's Collage. In Chapter 7, I conclude contributions from this body of work and suggest opportunities for future work. Within respective chapters, I reference how this thesis builds upon existing work. The end goal of this thesis is to provide insights into key challenges and to offer foundational tools for the advancement of memory aid research and smart home technology.

CHAPTER II

IMPACT AND SCOPE

Since its public debut in 2001 [109], the Cook's Collage received considerable attention from a wide range of audiences. Reactions to using the memory surrogate, designing the display, staging laboratory experiments, and to monitoring cooks have been polarized between enthusiastic praise and vehement dismissal. The research contributions of this chapter are *identifying* these disputed concerns and *understanding* their controversy. In the following sections, I review the dichotomy of responses regarding the four thesis components. For each, I identify stakeholders who appreciated the impact potential of my intended contributions, and I identify critics who could not condone the pragmatic limitations of this thesis. For all audiences, the primary goal of this chapter is to highlight relevant issues and challenges to be discussed throughout this document as contributions impacting various fields; thereby, *previewing* the implications from contributions of the subsequent four chapters. The auxiliary goal of this chapter is to acknowledge outstanding issues and challenges beyond the scope of this thesis to be addressed in the final chapter as future work. I end this chapter's survey of criticism and praise for the Cook's Collage in particular by surveying the rapid growth of smart home research and "smart spaces" in general during this time.

2.1 Example Situations Illustrating Memory Augmentation

Upon broaching the *need* for memory support in everyday cooking, I was confronted with dismissive appraisals. Older adults and academic pundits proclaimed, "I don't have this memory problem, so this effort is pointless." People who do not cook remarked,"Cooking errors are not critical, so investing in a supportive system is wasteful." Upon explaining memory *augmentation* for everyday cooking, unimpressed statisticians quipped, "How is the Cook's Collage successful if cooks are still making ingredient errors?" To these critics, I present stakeholders who appreciated the contributions of this research as follows.

2.1.1 Compelling Real-Life Need

At my first demonstration of the Cook's Collage, ordinary people who cook regularly at home immediately identified with the need for memory support of ingredient additions. Mothers of young children were especially enthusiastic about addressing their real need of providing a home-cooked meal for their children while being distracted by their children. Among the numerous groups visiting the Aware Home Residential Laboratory, elderly (female) adults were abuzz about benefiting from the Cook's Collage. These stakeholders resonated with the Cook's Collage because it dealt with their real-life need as a practical solution.

Children of aging parents volunteered the senior cooks to try the Cook's Collage. However, the older adults participants in my study (see Chapter 6) believed that their memory ability did *not yet* require the Cook's Collage, but they readily suggested friends and neighbors in their *peer* group whom they felt did need memory assistance. This indirect targeting of potential users for the Cook's Collage illustrated the memory introspection paradox as the biggest challenge I had to overcome in motivating need for memory support in everyday cooking. Similar to previous experimental results that discovered the memory introspection paradox, my experimental results also revealed that people who did not *perceive* or did not *admit* to memory needs were the very same ones who exhibited memory problems; thereby, introducing reasonable doubt for all who self-proclaimed no memory need.

For those who do not cook, underlying concepts in designing, implementing, studying, and evaluating the Cook's Collage can apply to other domains as discussed in respective chapters. In an independent random sampling of several hundred older adults attending lectures about memory and aging, the second most common admission involved remembering whether or not *routine* activities *have been* performed (comprising some 20% of the overall responses); thereby, representing the *kinds* of memory phenomena that are of interest (if not concern) to community-dwelling elderly adults as Plude and Murphy argued [88]. For those who judge everyday memory or routine activities such as cooking as unimportant, it is important to note that the life-changing decision of moving an elderly parent from independently living in his/her own home into an assisted living facility is typically based on how well dad/mom performs these instrumental activities of daily living (ADLs) that include cooking [66]. For those who truly do not require memory support, the fluid interactions of how the Cook's Collage managed status information of an open-ended activity can contribute towards Licklider's man-computer symbiosis especially regarding the current speed mismatch between man and computers; thereby advancing principles of human-computer interaction beyond the application of a memory surrogate.

2.1.2 Emerging Market Niche

Ever since my first demonstration, entrepreneurs and industry expressed enthusiastic interest and generous funds in commercializing features of the Cook's Collage as a viable product for the home, for memory, and for cooking. I believe their excitement stemmed from their anticipation of future technical possibility and of potential demand in the consumer market for addressing compelling real-life needs.

As one among the many Georgia Tech's Aware Home projects [59], the Cook's Collage has been included in a variety of noteworthy national news media coverage including CNN, Wired News, CBS Early Show, and The Wall Street Journal. I believed their interest and appreciation stemmed from keen curiosity and sensationalism to *entertain* novelty ideas in technology and service that could pique the interest of their viewing audience. As I tested the Cook's Collage, the news stories shifted towards the aging population as one targeted user group and towards healthcare technology as a societal issue relevant to all citizens. By investing as primary stakeholders in broadcasting novel and relevant applications such as the Cook's Collage, news agencies invested the viewing public as secondary stakeholders in the developing stories.

2.1.3 Between the Numbers

The fact that cooks were still committing ingredient errors even with the Cook's Collage available meant *success* for the memory surrogate. My underlying goal was to *supplement* not replace memory recall by keeping the *user* not the machine in control. By granting cooks the *choice* to use or not use the Cook's Collage meant that people were *able* to correct their memory slips by heeding the memory cues and were able to continue making ingredient errors by mistakenly ignoring the memory device. Not *presuming* that the Cook's Collage failed to eradicate ingredient errors, I classified numbers of ingredient errors with either use or non-use of the Cook's Collage in exacting the actual effect, and I recounted illustrative case studies to understand more clearly the effect. Individual differences and free will limited all three thesis statements in this document to only the *possibility* that Cook's Collage *can* provide and augment. Perhaps, future refinements to the Cook's Collage prototype would ensure that the memory display *does* augment memory recall.

In addition to the final analysis in Chapter 6, resulting data from a few more measurements (e.g., TLX, reliability questionnaire) listed in Appendix A, and six more study participants of a younger age group were not included in this report. I have already published some resulting findings from this set of younger adults [107, 108], and Julian Sanchez incorporated the reliability questionnaire responses into his dissertation [95]. I purposefully collected an excessive variety of measures along with multiple media footage of each experimental trial to hedge difficulties in determining a priori appropriate criteria for the Cook's Collage and to allow for further analysis of the same data set as future work.

2.2 *Expedited Breakdown and Prompted Realization*

Upon describing systematic procedures for expediting memory slips and prompting reflections from elderly cooks participating in laboratory experiments, my resulting findings were subsequently held in contempt. CHI reviewers wrote diatribes on how "artificially contrived" I designed my experimental setup. Ethnographers denounced the ecological validity of laboratory experiments (especially in smart homes) in deference to their field surveys for naturally occurring memory slips. Leading cognitive scientists reprimanded me about biasing use of the Cook's Collage. To these critics, I could concede my expedient methods as factors limiting the resulting findings, but not before I present rebuttals by reiterating long-standing appeals from experts in memory aid research as follows.

2.2.1 Systematic Simulation of Memory Slips

Responding to attacks in 1989 on everyday memory experiments dating back ten years to Neisser's reproach [83] as not "naturalistic" nor "everyday" even within certain context, West defended simulation studies (see glossary) as representing the "best situation" in terms of research because of its *high* ecological validity from using cues or stimuli that have potential utility in the real-world and its *high* generalizability from laboratory control and potential for programmatic replicability [113]. For everyday memory researchers like West whose leading prolific careers appreciate simulation studies despite criticizing opposition, I present a Repeated-Use Study (in Chapter 6) of the Cook's Collage as an *indirect* simulation study (see glossary).

I claim that my experimental method yielded ecologically valid memory slips in their physical and psychological state for the cook in the laboratory kitchen even though I artificially contrived situations to cause forgetting. However contrived and expedited, my experimental procedures were able to induce memory slips *repeatedly*;

thereby, engineering a *replicable* vehicle to study the lesser-known behavioral recourses to the well-known phenomena of memory slips. As Martin defended, "The advantage of experimental simulation as a method of studying cognitive failures is that it brings the phenomenon into the laboratory and allows the gathering of systematic data [73]." As an indirect simulation study, I concede that I artificially increased the difficulty level of ingredient additions and frequency of distractors to *maximize* production of memory slips. I suspect that same cognitive failures do occur in the wild but at a presumably sparse rate. As future work, these experimental procedures could be less expedited and less contrived to be more ecologically valid, or the Cook's Collage system could be deployed into the field to support real memory slips when they naturally occur.

I viewed reduced ecological validity in circumstances *leading up to* each ingredient error as a negligible criticism of this thesis. I deferred to expert psychologists whose extensive studies into circumstances leading up to memory slips indicated why interruptions are interruptive [36], what causes memory failures in everyday life [44], and which memory malfunctions cause people to forget or remember incorrectly [96]. I applied their lessons learned in designing a systematic procedure to induce memory slips. The premise of this thesis *starts* with a memory slip, the crux of this thesis contributes insights into its *aftermath*, but understanding its prelude was outside the scope of this thesis.

2.2.2 Well-Motivated Experiments of Real-Life Use

As prolific researchers studying performances of human cognition, Hollan, Hutchins, and Kirsh argued, "While the study of cognition in the wild can answer many kinds of questions about the nature of human cognition in real workplaces, the richness of real-world settings places limits on the power of observational methods. This is where well-motivated experiments come in.... Having observed this [real-world behavior] in natural settings we can set about designing more constrained experiments which test specific aspects of this [same] behavior" [48]. Their defense of laboratory studies over field studies under certain circumstances should be duly noted because Hutchins wrote the book about cognition in the wild [50]. Their two main arguments that the experiment method contributes observational power and focus on specific aspects from a natural behavior in the real world resonated precisely with my thesis objectives. With questionnaire responses to using various memory aids [39, 87, 60], this coping behavior *reportedly* exists in the real world. From my personal real-life experiences, I have observed successful and unsuccessful uses of memory aids for adding ingredients in everyday home cooking. From all these various uses of memory aids in natural settings, I focused on the natural behavior of visually scanning for memory cues to aid in memory recall. The laboratory setting permitted ample observation at many vantage points and in various measurements of this physical activity. Albeit less ecologically valid than observing cooks visually scanning for memory cues in the wild, I believe my evaluation focus confined inside the laboratory follows the advice of Hollan, Hutchins, and Kirsh.

Also in line with Hollan, Hutchins, and Kirsh, I carefully crafted *well-motivated* experiments. Typically, laboratory experiments in aging cognition research concede caveats in hedging criticism that participants (older adults more so than younger adults) may judge laboratory tasks to be *artificial* and *pointless*; thereby, reducing their motivation and subsequent performance results. Hence, ill- or un-motivated experiments may exacerbate performance comparisons of unengaged older adults against earnest younger adults. Addressing this concern, an increasing number of laboratory experiments are contriving *familiar* real-life tasks (e.g., preparing breakfast) to maintain ecological validity in the experimental setup as "realistic and *involving* so that the participants are motivated to *succeed* [24]." These experimentalists have agreed with and want to learn from my well-motivated experiments of real-life use.

2.2.3 Between the Breakdowns

As an expert in *studying* everyday cognitive failures, Martin compared three major methods of observation (e.g., diary study), experimental simulation (study), and questionnaire (e.g., self-ratings) by remarking,"Perhaps the most informative of strategies is to investigate how individuals' questionnaire scores relate to their performances on experimental tasks. The discovery of systematic associations between the two types of measure would suggest areas of common mechanism that could significantly increase our understanding of the generation of cognitive failures in everyday life...." [74]. She added,"In *applied contexts* particularly, it may be useful to be able to supplement questionnaire's self report information by objective performance data"[73]. The method procedures in this thesis build upon Martin's comparative analysis between subjective self-reporting and objective recording of memory performance as applied to ingredient additions in everyday home cooking. The findings revealed stark contrasts between perception and reality resulting from either participants' unintentionally inaccurate self-*assessment* (i.e., suggesting memory introspection paradox that is within the scope of this thesis) or participants' intentionally inaccurate self-*admission* (i.e., suggesting human bias of "Do as I say, not as I do" that is beyond the scope of this thesis).

Unlike Martin's *post*-comparisons for analysis purposes only, I shared the objective measures with participants *during* their Repeated-Use Study to prompt internal reflection of their existing memory habits and to open subsequent exploration of new memory aids. Hence, I conceded to criticism that informing participants of their performance errors affectedly increased their subsequent use of the Cook's Collage because understanding *why* cooks came to *use* the newly introduced memory surrogate was beyond the scope of this thesis and left as future work. On the other hand, I did investigate why cooks continued to *not use* the Cook's Collage even when given (too much) information that their memory performance *could* benefit from memory aid use; thereby, contributing in a thesis statement that *barriers to using provided memory support can include unawareness of memory need and predilection to own memory ability and routine.*

2.3 Design of In Situ Application for the Future Home

Central in the design debate over the Cook's Collage was how it *would* fare better than (conventional) design alternatives. Unfortunately, I could not address these speculations because I *chose* not to pursue a breadth-first comparison of design approaches. I identified synthesizing *known* components into memory devices as the job of a design practitioner whereas *exploring* new memory uses from new design ideas as the job of a human-computer interaction researcher. Still, I duly noted suggested design alternatives for the Cook's Collage as future work.

Central in my design stance of the Cook's Collage was how it *did* exemplify as *proof of concept* an in situ application that augmented a specific need (in this case, memory recall of ingredient additions) for the future home. I defend my design rationale in Chapter 3, but I mention here how the underlying design principles of the resulting display features caught the attention and approval of active leading designers in human computer interaction, ubiquitous computing, and smart homes.

2.3.1 Exemplar "Design of Future Things"

In the field of human-computer interaction, Don Norman is a highly esteemed researcher with a prolific career of giving opinions that impact the design community at large. He is reputed for being critical of poor design prevalent in existing products and stingy about bestowing praise for good design in a select few. Norman advocated how the Cook's Collage (and Microsoft Research at Cambridge's HomeNote project [97]) should serve as an exemplar for future human-computer interaction design in his new book *Design of Future Things* [86]:

"Notice the important distinction between the devices of the Cambridge and Georgia Tech projects and those of the traditional smart home. Both groups of researchers could have tried to make the devices intelligent.... This is, indeed, a common preoccupation of researchers in the smart home field. Similarly, the researchers in Atlanta could have made an artificially intelligent assistant that read recipes, prompting and instructing every step of the way, or perhaps even an automated device that would make the cake itself. Instead, both groups devised systems that would fit smoothly into people's life styles. Both systems rely upon powerful, advanced technology, but the guiding philosophy for each group is augmentative technology, not automation.... The problems that we face with technology are fundamental. They cannot be overcome by following old pathways. We need a calmer, more reliable, more humane approach. We need augmentation, not automation." I thank Don Norman for recognizing and extolling the user interaction design of the Cook's Collage stated in my thesis claim: *User interaction with accurate memory support that complements and supplements rather than interferes with memory practices, activity constraints, and environmental surroundings* can effectively augment memory recall.

Along with his written praise, Norman appeared to me visibly envious that *he* had not thought of Cook's Collage when muttering repeatedly, "Such a clever design! Something I could use, especially the numbers." It is my hope that Norman's standing position as a world spokesperson of human-computer interaction design and thereby knowledgeable in many various design alternatives will silence design criticisms of the Cook's Collage just long enough for memory aid designers and HCI researchers to (re)discover its underlying design contributions (detailed in Chapter 3).

2.3.2 Exemplar In Situ Application

In her survey of ubiquitous computing applications representing Weiser's vision of calm computing [112], Rogers described the Cook's Collage as "replay[ing] a series of digital still images in a comic strip reel format depicting people's cooking actions *in situ* [91]," with the term *in situ* defined as "in its original place; in position" [7]. Albeit remiss in their written publication, the Cook's Collage was praised in their subsequent oral presentation as an exemplar in their design comparison of "smart living objects" within the home [23]. Recently increasing in numbers, citations like these identified design stakeholders in the Cook's Collage because their comparisons of in situ applications and calm computing affirmed my design intentions and objectives as stated in my thesis claim: *Visually summarizing activities by capturing items used within the activity in the same physical surroundings* can provide sufficient context in recalling memory for actions.

2.4 Sufficient Monitoring

Upon describing how I monitored kitchen activity and simulated the Cook's Collage for the user experience, my technical infrastructure was criticized as too much technology required for too little an automated service. Skeptical engineers cautioned about the unfeasible automation of a memory oracle. Anxious academics raised ideological concerns about camera privacy in the home and about technology dependency from the memory surrogate. To these naysayers, I agreed with their concerns in general, but this thesis will show that their concerns did not apply within the scope of this project in particular.

2.4.1 Camera Privacy in the Home

Upon pointing out cameras for the Cook's Collage, the idea of *Big Brother* defined as "an omnipresent, seemingly benevolent figure representing the oppressive control over individual lives exerted by an authoritarian government [2]" rears an uneasiness for the general use of cameras in the home. Many academic pundits voiced this *abstract* fear of the *potential* from monitoring technology; however, everyday people whose *direct use* of the close-up photographs in the Cook's Collage dismissed these blanket assumptions of *Big Brother* and positively accepted the cameras as noninvasive and harmless. The two small cameras used for the Cook's Collage had specific purpose, restricted coverage, limited distribution, and limited lifespan. The video captured necessary details of cooking to be effective as a memory surrogate and did not expose extraneous details that would have been cause for alarm. In short, my specific camera uses for the Cook's Collage rendered concerns of camera privacy in the home nonapplicable. Still, the ideological camera debate spurred a worthwhile survey of accepted smart home technology [20], and the physical camera setup has been replicated in related kitchen prototypes [99].

2.4.2 Technology Dependency

Reminiscent of the calculator debate that students using calculators to perform mathematical computation would lose this mental skill [100], the Cook's Collage have been dismissed as detrimental to memory recall over long-term use by atrophying memory ability. I would have heeded this cautionary tale in general, but the specific limitations of the Cook's Collage rendered technology dependency nonapplicable. That is, the Cook's Collage does not proclaim to be accurate or consistent unlike the calculator; thereby, impelling cooks to use only upon forgetting. On the other hand, this technology tale emboldened my usage scenario for the Cook's Collage by arguing parallel benefits from calculator usage. Namely, people who would normally be turned off to activities because of frustration or boredom can increase their enjoyment. Tasks are simplified so people can determine best methods for solving problems. Ultimately, people spend less time on tedious cores, more time on understanding and solving problems. I believe proponents of calculator usage would likewise be proponents of the Cook's Collage since my preliminary data on younger adults (not included in this document) suggested similar emerging trends [108].

2.4.3 Quality of Service

The main engineering *assumption* was that memory support would *require* a high quality of service (i.e., always correct, precise, and immediate) and therefore massive engineering support to be useful. Unlike most system prototypes built upon specifications that an ideal oracle is futuristically possible or that a manageable service is predictably pending, I committed to no assumptions nor guarantees about the quality of service for the Cook's Collage. I employed a wizard of Oz simulation as a *scaffolding testbed* to introduce a range of recognition inaccuracies and processing delays so that participating cooks could *calibrate* their level for quality of service. In doing so, I concede to technology criticism of over-engineering a monitoring system that still required human operation because my *research* goal of *informing* quality of service obligated a *maximal* testing system that I hoped would recommend eventual *engineering* requirements for *minimal* automation. Although not systematically studied, the resulting spectrum of user experiences indicated *individual* differences in tolerating system delay and *ingredient* differences in tolerating system inaccuracy (detailed in Chapter 4). This emerging trend suggest points in diminishing value on quality of service; thereby, addressing engineering concern regarding return on investment. My lessons learned in determining quality of service via the wizard of Oz approach should be of interest to active researchers building wizard of Oz toolkits (e.g., [62, 30, 71, 69]) for context aware applications.

2.4.4 Recognition Requirement

The main engineering concern for the Cook's Collage was that an ideal memory oracle (i.e., omnipresent in monitoring, omniscient in recognition) would be unfeasbile or impractical, so I decided against building a memory oracle. Instead of striving for the highest ability of activity recognition, I aimed for the lowest threshold of user requirement. How smart was smart *enough*? In my thesis statement, I hypothesized that *absolute* identification of ingredients (e.g., sugar, flour, salt) could be reduced in precision to *relative* identification of *this* and *that* ingredient when grounded in shared context "within the activity in the same physical surroundings." I achieved this recognition requirement by restricting the monitoring system to differentiate only between *same* and *new* ingredient additions (as detailed in Chapter 4). The resulting user experiences demonstrated that smartly sharing distributed cognition can alleviate feasibility requirements in monitoring repetitive actions while sufficiently preserving usability and usefulness in the memory aid.

My intent in defining a sufficiency threshold was not to curb advancements in computational perception. On the contrary, I contributed anonymized video footage (from the Repeated-Use Study in Chapter 6) as training data sets for further analysis of recognition heuristics beyond the scope of this thesis that Raffay Hamid incorporated in his dissertation towards an automated analysis of everyday human activities [38]. Other domestic laboratories are now similarly collecting in situ training data for context-aware ubiquitous computing applications [53]. I pursued a sufficiency threshold because many researchers in activity recognition and ubiquitous computing requested my alternative approach in ascertaining *user* requirements rather than arbitrating extraneous system features (e.g., weighing ingredient measurements). I contribute lessons learned from monitoring over 226 cooking trials.

2.5 Summary: Changing Times

Back in 2001 when I started this project, the field of smart home technology was just burgeoning as well. Georgia Tech's Aware Home[59] had just opened, and more living laboratories of domestic research (e.g., Mozer's Adaptive House[81], MIT's PlaceLab[54], Gator Tech Smart House[42], Ubiquitous Home[115], Ocha House[10]) followed over time. Throughout this project as the principal investigator, I debated the many aspects presented in this chapter of the Cook's Collage alongside researchers who albeit seasoned in ubiquitous computing and human-computer interaction were also navigating the then unexplored domain of smart homes. I consulted with the long-established history of memory aid research for fundamental theories of existing memory aids and strategies, but I found little ongoing exploration in applied context or of memory devices. As a novice with only my inventive intuition, anecdotal inspirations, and unconventional proposals, I struggled in my biggest challenge of convincing senior researchers to reconsider the intricacies of the otherwise seemingly trivial illustration of augmenting memory recall for everyday home cooking. It was only through iterative discussions with my critics that I came to understand their pragmatic concerns for and ideological dismissals of the Cook's Collage as *just* one of many hopeful attempts at "smart spaces" [92], so it is only with learned expertise, produced replicable results, and won endorsements from leading experts that I can now (two years after my thesis defense) convincingly promote the Cook's Collage as a proof of concept *exemplar* in display design, wizard of Oz implementation, simulation study procedures, and qualified case study analyses to *start* shifting future research directions for smart spaces in research communities of smart home technology, ubiquitous computing, and human computer interaction.

CHAPTER III

COOK'S COLLAGE DISPLAY

In this chapter, I detail the Cook's Collage display features, document my design rationale, and establish the design component of my thesis questions. The research contributions of this chapter are lessons learned in iteratively refining display features for the Cook's Collage that user studies demonstrated to be beneficial, detrimental, or superfluous. The chapter begins with detailed description of the augmented kitchen and display features for the Cook's Collage that resulted from iterative design. I describe visual features and animation mechanisms for the Cook's Collage which I illustrate with an example cooking session. Then, I reflect upon key design decisions by reviewing user feedback of the four earlier prototypes, identifying strengths and weaknesses that precipitated design refinements. Also, I review previous work in similar design approaches that informed and inspired my rationale. With the success of the Cook's Collage as a viable application of design features that provided memory recall of ingredient additions, I contribute its underlying design concepts as a general framework for memory aids I term deja vu displays to provide recall information of tedious memory tasks within an enjoyable activity. I end this chapter by previewing how these design components contribute to my underlying thesis questions.

3.1 Augmenting the Home Kitchen

Upon entering the kitchen in the Aware Home Residential Laboratory (see Figure 2), the physical space resembles an ordinarily contemporary western home kitchen with a microwave, rows of countertop space for food preparation, columns of overhead and bottom cabinets for storage, and a large square footage of floor space. The remaining kitchen components include a sink, stove, and refrigerator; hence, triangulating a key

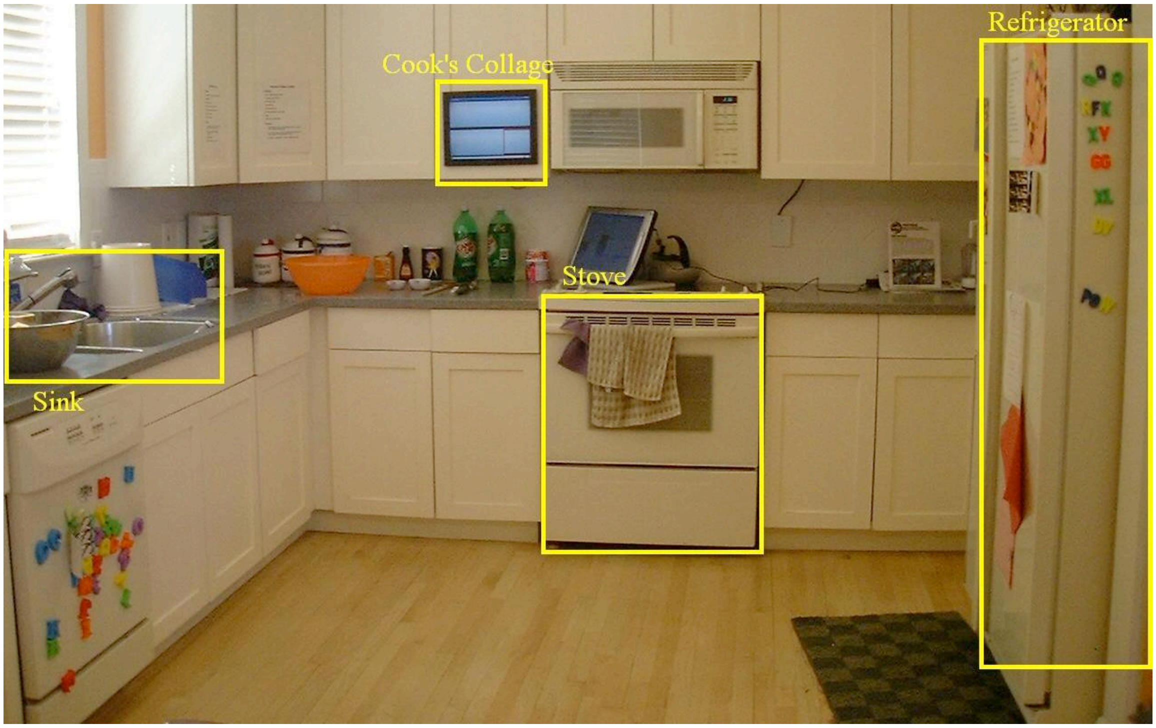


Figure 2: Location of Cook's Collage within the AwareHome kitchen laboratory

Figure 3: Location of cameras capturing ingredient photographs

layout principle defined by kitchen designers as the *kitchen triangle* that efficiently regulates work flow. With the Aware Home kitchen as the testing facility, I added the following components to create the Cook's Collage system.

For the Cook's Collage display, I mounted a 13-inch liquid crystal display (LCD) into an overhead cabinet beside the stove. The slim encasing of the flat panel for the LCD, snugly embedded within the commonplace cabinet fixture, presented a physical artifact resembling framed art rather than an obtrusive computer or surveillance monitor. I positioned the information display not to impose physically upon the cook's line of sight while working with ingredients on the kitchen countertops because visual updates to the Cook's Collage display may distract the cook's attention from cooking; however, I did want the memory display to be easily and quickly accessible when needed with only an eye glance up from countertop space as envisioned in Chapter 1's usage scenario. The horizontal position coincided with the stove's location as one of the three work stations along the kitchen triangle, and the vertical position of the Cook's Collage display corresponded to the eye-level of most cooks when standing beside the countertop aisle. I added the LCD display as the only output component in the Aware Home kitchen for the Cook's Collage system.

For the monitoring component of the Cook's Collage system (detailed in Chapter 4), I mounted two small video cameras that continuously recorded video footage of cooking activity on the countertop space at locations shown in Figure 3 that met two key requirements. The horizontal position of the two cameras provided complete video coverage of the designated countertop space (defined in following section). The vertical position of the cameras were hidden underneath the overhead kitchen cabinets to be not obtrusively visible *in the face* of the cook when standing beside their assigned work area. Moreover, the cameras captured activity constrained to the countertop such as tools, ingredients, and hands; they did not capture the faces or full bodies of people in the kitchen. This *out of sight, out of mind* strategy sought to temper privacy concerns from being consciously monitored and to discourage *cooking show* theatrics from performing for the camera. In addition to these cameras, I monitored the ambient noises from the kitchen. In a separate room, a human operator (i.e., wizard of Oz) viewed the streaming video footage feed and listened to ambient sounds from the kitchen to simulate activity recognition of ingredient additions for the Cook's Collage system. These two video cameras and the ambient audio sounds were the only two types of input components that I *added* for the Cook's Collage system to the otherwise ordinary home kitchen.

3.1.1 Surveillance Space

I constrained the surveillance area of the Cook's Collage so that any user activity outside of these defined areas would be done without the benefit of the memory aid. I arbitrarily designated the left corner countertop space between the sink and the stove in the kitchen as the primary preparation area for the cooks to add ingredients into a mixing bowl that was also assigned to a prefixed physical location. These two physical constraints were initially purposed for pragmatic scaling and seen as an application limitation; however, the clear demarcation of physical space became an advantageous feature for the Cook's Collage display.

3.2 Display Features

In this section, I complete the usage scenario introduced in Chapter 1 by detailing the visual features and animation mechanisms of the Cook's Collage display. First, I describe three visual components and the underlying animation mechanism that orchestrates these key pieces in concert. Then, I illustrate the display features with an example summary produced from an actual cooking session.

3.2.1 Photographed Ingredient Addition

For every ingredient added to the mixing bowl by the cook, a representative photograph is presented on the Cook's Collage display. From the viewpoint of the mounted cameras looking down upon the kitchen countertop, the photographs consisted of close-up images showing the cook's hands adding an ingredient, sometimes capturing the motion blur of the ingredient being poured into the mixing bowl. The cameras' close range maximized identifiable details of the ingredient and measuring utensil. The cameras' side angle minimized occlusions from the cook's body and avoided extraneous details of the cook's face. Notwithstanding the automated light correction from the cameras' hardware automation, the Cook's Collage intentionally presented the captured photographs in their raw form without any further image abstraction or enhancement. Each photograph was displayed at 352x288 image resolution, so a maximum of six photographs could fit physically within the 13-inch LCD.

3.2.2 Annotated Number of Repeated Ingredient Addition

The Cook's Collage exposed repeated ingredient additions by annotating the running count as a large yellow number against a black background in the top-left corner of the corresponding ingredient photograph. If an ingredient was added only once (i.e., not repeated), its photograph was not annotated. If repeated counts of an ingredient were added in succession, the Cook's Collage compressed the repetitive ingredient photographs into slim vertical gray bars that represented ellipses and showed only the photograph of the ending ingredient addition.

3.2.3 Animated Sequence

The Cook's Collage used a 2x3 grid layout to present the six ingredient photographs. The horizontal film reel borders clustered the rows of photographs together, suggesting a horizontal reading of the photographed ingredients. I chose the film reel motif to accentuate the reality of the captured photographs and the chronological sequence of the ingredient photographs. With every new ingredient, the ingredient images on the Cook's Collage shifted left by one position. The bottom-right photograph always displayed the most recent ingredient, so the Cook's Collage always showed the six most recent ingredients only along the 2x3 grid layout.

3.2.4 Indicated Time Delay

Due to processing time by the monitoring system, photographs did not immediately appear in the Cook's Collage display. A photograph could be delayed by as much as nineteen seconds, but a one second delay was more typical. Below the 2x3 grid of the photographed ingredient additions, I added the tortoise-and-hare timeline to indicate visually the current time delay from the moment the cook added an ingredient to when Cook's Collage would show the ingredient photograph. Inspired by the parable of the hare and the tortoise race [12], the tortoise represented the monitoring system (i.e., wizard of Oz), and the hare represented the cook. At the right end, a checkered flag depicted the end of the race (i.e., completing the recipe). The directional orientation of the hare relative to the checkered flag indicated the progressing direction of the race. At the left end, a speed meter posting of 30 visually marked where the tortoise would be positioned in the event of a 30-second time delay from the Cook's Collage system. As the tortoise lagged farther behind the hare in space towards the speed meter, so did the Cook's Collage system lagged further behind the cook in time. As the tortoise moved closer in distance towards the hare, so did the Cook's Collage get up-to-date on photographing the cook's ingredient additions. The changing physical distance between the tortoise and the hare visually animated processing delays at the time that the Cook's Collage system may encounter in generating the Cook's Collage display from the moment the cook added an ingredient. In addition to *overall processing* delay were *network* delays *per* photograph reflected as changing traffic color borders (i.e., red, yellow, green) around the bottom-right ingredient photograph.

3.2.5 Example Punch Recipe Summary Sequence

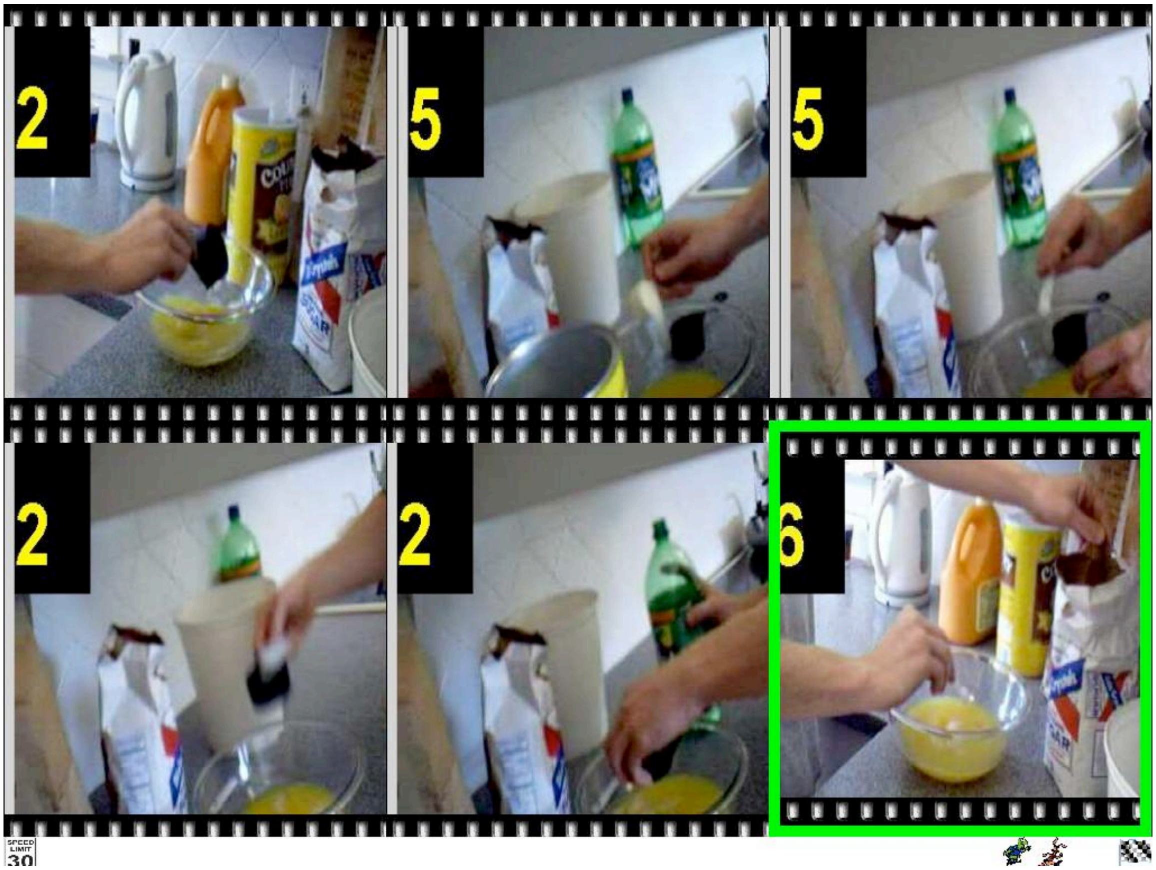


Figure 4: Cook's Collage for example punch recipe summary

Figure 4 shows a resulting summary that the Cook's Collage generated from an actual cooking session. By visually scanning the Cook's Collage display from the bottom-right corner photograph to the upper-left photograph, the cook could have reviewed that he had most recently added the 6th scoop of sugar, preceded by two scoops of added soda, preceded by two scoops of added ice, preceded by multiple scoops of added sugar ending with the 5th scoop, preceded by multiple scoops of added lemonade powder ending with the 5th scoop, preceded by two scoops of added water. The cook could have noticed the tortoise-and-hare at the bottom of the Cook's Collage display; thereby, understanding that the memory aid to be approximately two seconds delayed in displaying up-to-date photographs of his most recent ingredients.

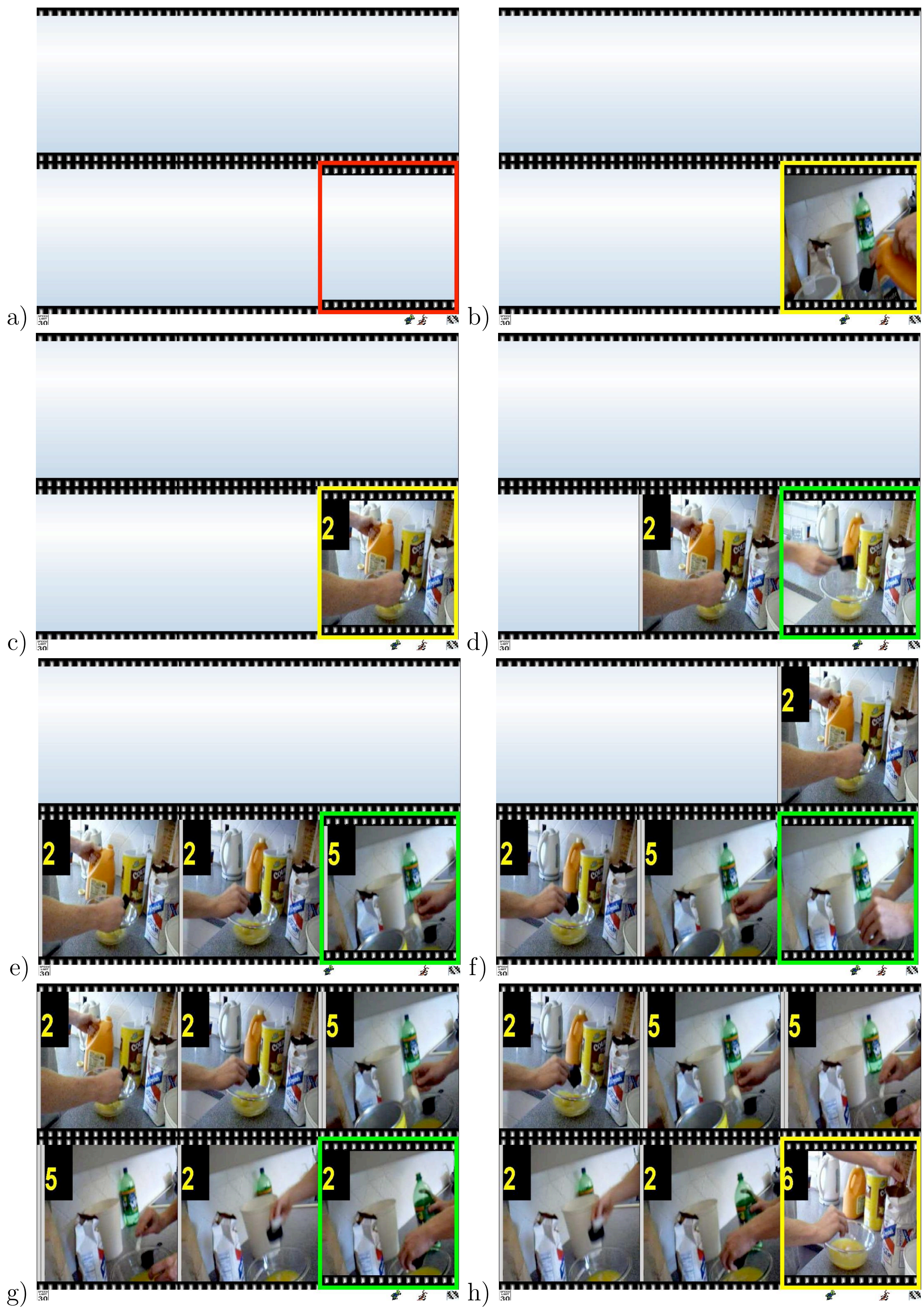


Figure 5: Animation sequence for example punch recipe summary

As a summary of the display features detailed in the preceding sections, Figure 5 demonstrates how the Cook's Collage transitioned through photographed ingredients of the cook adding ingredients that resulted in the punch recipe summary shown in Figure 4. The cooking session began with empty images along the 2x3 grid of the Cook's Collage and the tortoise positioned right behind the hare on the bottom timeline as shown in Figure 5a. After the first ingredient addition, the Cook's Collage added a representative photograph capturing the ingredient being added in the bottom-right corner as shown in Figure 5b. After the cook added the same ingredient again, its accumulating count annotated the new photograph of the repeated ingredient as shown in Figure 5c. After the cook added a new ingredient, the photograph of the previous ingredient shifted left one position to make room for the new ingredient photograph placed in the bottom-right corner as shown in Figure 5d. With this procedure, the procession of photographed ingredients filled up the bottom row of the 2x3 grid as shown in Figure 5e. With the bottom row full, the next added ingredient shifted photographs to the top row as shown in Figure 5f. With this procedure, the photographed ingredients filled up the entire display with six photographs as shown in Figure 5g. With the display full, the top-left photograph transitioned off the display to make room for the new ingredient as shown in Figure 5h. With this procedure, the procession of photographed ingredients continued to fill the Cook's Collage until the cook completed the punch recipe. At any point during this cooking session, the cook (i.e., user) could have glanced up towards the Cook's Collage for assistance in recalling information regarding his recent ingredient additions.

3.3 Lessons Learned in Design Refinements

The display features of the Cook's Collage presented in the previous section were the culmination of incremental improvements from four major design iterations (see Figure 6b, 7a, 7b, 7c) until no further user concerns remained. In this section, I explain how user feedback from simulation studies conducted in the Aware Home kitchen laboratory and external viewer reaction to the Cook's Collage demonstrations directed design refinements.

3.3.1 Tale of Two Scenarios

At the initial public viewing of this project [109], I demonstrated two particular memory problems I personally identified with in everyday home cooking. Figure 6a shows the initial design concept that supported cooks in recalling elapsed times of two different stove burners, and Figure 6b shows the initial design concept that supported cooks in recalling recent ingredient additions. With these *proof of concept* candidates, I solicited reactions that informed my selection for a usage scenario. That is, how compelling were memory problems of forgetting the elapsed times from overlapping cooking and of forgetting ingredient additions? Were these identifiable situations that people would admit to having experienced? Would cooks consider memory assistance to be of added value in resolving these situations?

I discovered that everyday people empathized with forgetting ingredients and appreciated the novel memory support much more empathically than they acknowledged forgetting cooking times. I learned that entrepreneurs eagerly rated my design concept for tracking cooking times as a patentable product for commercial market but that the design space for tracking ingredients held more opportunity for research investigation. Based on these reactions, I chose to support ingredient additions.

3.3.2 Tale of Two Viewers

Throughout design iterations for the Cook's Collage, I solicited feedback from two distinct perspectives: those who were participating cooks in the Aware Home kitchen (i.e., users) and those who were not (i.e., non-users). Understanding how differently these categories of viewers reacted to the Cook's Collage display yielded insight that informed my design decisions.

a) 

b) 

Figure 6: Design concepts for memory support of a) elapsed time and b) ingredients

In determining which information would be useful in a cooking memory display, I intentionally overloaded the earlier prototypes with many, possibly pertinent information to cull from progressively. From the initial design concept (see Figure 6b), the contextual information surrounding the photographed ingredient was not perceived as any added value. Beyond the readability issue, I learned that these explicit information (i.e., identifying the cook, identifying the cooking items, timestamping the cooking steps, and categorizing the cooking steps) were redundant given the context of the physical kitchen stage that implicitly and more effectively displayed the same information. From the initial user study of (see Figure 7a), I learned that having the recipe juxtaposed immediately next to the Cooks Collage did not ensure that cooks would refer to the memory display. As a result, I removed these contextual and peripheral information from the Cook's Collage to maximize display space for the main component that cooks did value (i.e., photographed ingredients). With just this visual and the simple organization for summarizing the recipe, the cooks reviewed the Cook's Collage as sufficient in recalling memory for actions.

In contrast to the participating cooks who required only a moment's time to query and review their *memory* display, non-participating cooks studied the novel *information* display at great length. These unfortunate individuals did not have the benefit from physically being in the Aware Home kitchen and did not have *first-hand* user experience of physically doing the recipes (i.e., naturally encoding memory for actions) with the captured ingredient items. Understandably, these disadvantaged viewers found the photographed images disorienting with "too much detail" that were very cluttered to recognize, and they rated the Cook's Collage as very confusing in interpreting the visual summary from cooking activity. Even experienced HCI experts dissapproved of the display design as insufficient and unsuitable for the general viewer, and some constructively suggested displaying abstracted information (e.g., text, generic images) instead. Based on how these two categories of viewers strongly defended and argued their polar reactions to the Cook's Collage, I concluded in my thesis statement that *visually summarizing activities by capturing items used within the activity in the same physical surroundings can provide su?cient context in recalling memory for actions.*

3.3.3 Tale of Two Ambiguities

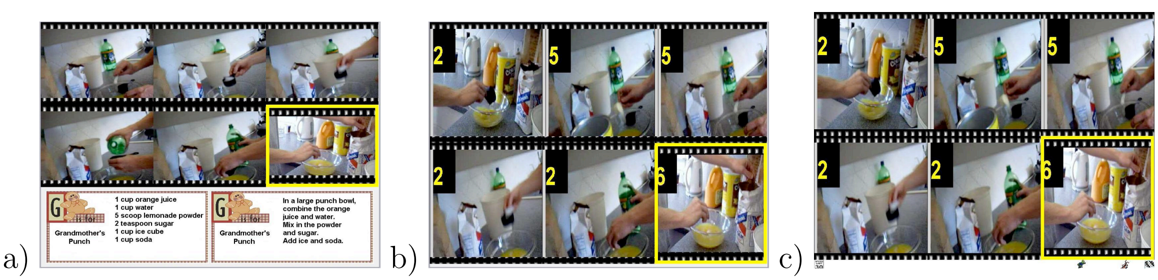


Figure 7: Design refinements to focus and disambiguate visual summary from the same moment in example punch recipe

In designing Cook's Collage as a visual summary, I learned how *visuals* and *summaries* can be ambiguous, and I was able to resolve these ambiguities through a series of trial-and-error testing of iterative design in the Aware Home kitchen laboratory.

From the initial user study, participating cooks with prototype from Figure 7a commented that some images were too blurred from the motion of adding ingredients and too grainy from the low resolution (i.e., 176x144) to recognize easily which ingredients were captured on the visual display. By removing the recipe from the display, I was able to increase the image resolution; thereby, allotting more space for bigger and clearer images for the subsequent prototype 7b of which satisfied the participating cooks. With each image resolution (352x288) decided by users and the overall display resolution (1024x768) constrained by the physical device, an optimal composition yielded a 2x3 arrangement of six images. If the physical LCD were larger, the Cook's Collage could fit more than six images.

Beyond visual ambiguity *within* each photographed ingredient was visual ambiguity differentiating *between* each image. Also from the initial user study, participating cooks with prototype from Figure 7a commented that photographed images of repeated ingredient additions were visually similar to one another and that these repetitive images quickly occupied the entire visual summary. In the subsequent prototype (see Figure 7b), I introduced number annotations to address the visual ambiguity, and I introduced visual ellipses to address the inefficient use of visual space. However, this design refinement introduced a new visual ambiguity from reusing display space for repeating ingredients. In the subsequent prototype (see Figure 7c), I introduced the tortoise-and-hare timeline and color changing border for the most recent ingredient to address this progress ambiguity. I learned that the participating cooks made use of the timeline feature but ignored the color changing border feature.

3.4 Building on Success from Previous Work

In the previous section, I explained how user concerns and comments informed design *refinements* between prototype iterations. In this section, I describe how my choices in design *fundamentals* were grounded in successfully tested design approaches or inspired from aspiring visions set forth by pioneering researchers.

3.4.1 Confirming Cognition in the Wild

What to display determined my primary decision in designing the Cook's Collage. My *visual* choices were inspired from existing techniques in visual design, and my *cognitive* choices were grounded from memory strategies identified in memory research to be used frequently, naturally, and successfully.

In 1986, Norman and Miyata presented fundamental requirements for reminders

- as *signal* to indicate that *something* is to be remembered (e.g., tying string on one's finger), and
- as *description* to aid in retrieving *what* was to be remembered (e.g., dirty dishes reminding of washing dishes) [79].

However, transforming these conceptual goals into actualized components in practice has yet to be established by a general design framework. I have noted from field studies (e.g., [19, 50, 68]) and from my own user studies that individual-specific, context-rich, and situation-based design features made for successful reminder descriptions. Mediating between these abstract goals and their concrete uses, I constructed visual mechanisms for the Cook's Collage to capture unique visual features that were meaningful to participating cooks.

In summarizing activity, the established advantages of mental retracing as an *internal* memory aid grounded my choice of a sequential layout for the Cook's Collage as an *external* memory aid. In an interview survey of internal memory strategies (e.g., first letter mnemonics, rhymes) for 30 students, mental retracing was self-reported as the most *frequently* used internal memory aid (97% ever used, 23% used more than once per week) [39]. It is important to note that mental retracing is a *pure* retrieval strategy (i.e., requiring no special encoding effort to use it); thereby, separating it from other internal memory aids. Even memory researchers self-reported using and recommending memory training (e.g., formal mnemonic systems) the least, but the memory experts self-reported using and recommending external aids (e.g., writing things down) the most [87]. A similar trend was reported from the same 30 students mentioned above. Particularly, memo (to self) was self-reported as 97% ever used and 43% used more than once per week; and putting something in special place was reported 100% ever used and 40% used more than once per week. Inspired by such self-reported trends of existing memory practices, I designed the Cook's Collage as a memo to self in a designated location for cooks in the Aware Home kitchen.

In summarizing video, proven techniques in the visual arts influenced my choices of visual features for the memory display. I was inspired by television shows that presented concise, montage replays from previous episodes recapitulating salient events that already transpired; thereby, providing relevant context for ongoing storylines. I was intrigued by automated algorithms that compressed video segments into keyframe images in a comic-style layout [18] and that chronicled an individual's multi-day conference participation with generic comic-style avatars [102]. I learned that comic books commonly employed sequential flow as the most basic layout in visual design [75](e.g., top-down left-right flow for western readers); thereby, reinforcing the semantic structure for memory strategy of mental retracing. I learned that *percent-done progress indicators* can offset people's natural preference to *constant* over *variable* system response times [82]; thereby, motivating the tortoise-and-hare timeline feature for the Cook's Collage.

3.4.2 Deferring to User Discretion

When to assist memory recall determined my second key decision in designing the Cook's Collage. I chose to defer to user discretion in *deciding if* memory assistance is desirable, *initiating when* to query for memory support, and *settling whether* to adhere to given memory information.

From the designer's perspective, my one exemplar from current technology that reinforced the user interaction with the Cook's Collage display was *closed captioning* for television viewing [3]. The written text of the transient audio transmission appears within the physical setting of the televised program only if and when the viewer requested (for the complementary and potentially supplemental) information by turning on the information display and by visually scanning the summary transcript. Moreover, the viewer can choose to ignore or use this secondary broadcast at any point while watching the televised broadcast. In this way, I positioned the memory display within close physical proximity to the supported activity. The LCD had an on/off button, and the cook needed only to glance at the visual summary of the Cook's Collage; thereby, maintaining the option at all times to use or to ignore the memory aid. Unfortunately, smart (home) technology at large has yet to adopt deferring to user discretion as a standard principle in user interaction design as Norman has surveyed, so he is similarily advocating that "augmentative technology should be voluntary, friendly, and cooperative. Use it or ignore it, as you wish [86]."

From the user's perspective, the ideal memory aid should *not distract* from current activity but remind user *when* something has to be done immediately [79]. However, It is important to note that these design requirements are potentially conflicting. Therefore, I consulted *trigger analysis* for categories of naturally occurring memory triggers to survey "Why do things happen when they happen and do they happen at all?" as follows: [29]

- Immediate triggers occur immediately after the previous activity reaches completion,
- Temporal triggers occur at regular intervals or after particular delays,
- Sporadic triggers occur when the individual responsible for some action remembers that it must be done,
- External events occur when prompted by alarms and other timed signals, and
- Environmental cues occur when artifacts in the environment remind.

From this list of identified breakdowns and failures in work flow, only the last two triggers (i.e., external event, environmental cues) need externally *active* rather than *passive* reminding. Hence, I designed the Cook's Collage *not* to distract from the ongoing activity by alerting *probable* memory problems as I describe next.

3.4.3 Making Memory Visible

How to assist memory recall determined my third key design decision. I sought to endow the Cook's Collage with visibility, redundancy, distribution, persistence, common ground, and persuasion.

My underlying design goal was to make memory visible. I was informed by *display-based problem solving* that illustrated via case studies (of making coffee every morning, the *Tower of Hanoi* puzzle, and algebraic equations) how introducing physical objects as natural placeholders within the activity reduced complexity of the mental process and how removing these physical objects increased susceptibility to cognitive failures [65]. In this way, the Cook's Collage displayed physical objects used in the recipe as placeholders within cooking. However, the Cook's Collage was not an integral object within the primary activity; thereby, minimizing the user dependency of display-based problem solving that was prone to cognitive failure.

My corollary goal to making memory visible was to distribute (potentially redundant) memory. I drew upon lessons learned from different domains and different emphases that sought to achieve the same underlying goal of making visible information that was originally invisible by distributing cognition. Norman described this transformation of information as *knowledge in the head* becoming *knowledge in the world* [85]. More formally defined, "whereas traditional views look for cognitive events in the manipulation of symbols inside individual actors, distributed cognition looks for a broader class of cognitive events and does not expect all such events to be encompassed by the skin or skull of an individual [48]." More specifically defined and motivated for older adults, environmental support "externalizes task components, thus reducing the need for self-initiated mental processing. For example, providing memory cues reduces the need for retrieval. Such support should reduce age differences because older adults can experience declines in self-initiated processing [80]."

Additionally, I chose to make memory *persistent*. From the array of traditional home displays, I was inspired by the wall clock (i.e., clock mounted on a wall). While the clock face maintains a *persistent* range of time (i.e., typically 12-hour), the clock hands *constantly* update the current time. In a similar way, the Cook's Collage updated new ingredient information within its window of recent ingredients. For the array of future digital displays, I was inspired by Weiser's vision of calm computing to less information overload from constantly updating information: "Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods [112]." Following this approach, the Cook's Collage captured the rich visuals of the kitchen surroundings to maintain the user's immersion in their ongoing cooking.

Beyond providing *quantitatively accurate* memory information, I wanted Cook's Collage to present *qualitatively convincing* memory recall. Experimental results have illustrated how the decision process in distinguishing between memories of *actually* doing and memories of *imagining* doing can confuse many people [15]. Therefore, I wanted the visual summary to suggest *believability* much like surveillance photographs of traffic violations that now accompany mailed citations provide evidence to the offender of the committed action. In cases where the accused has no supportive confirmation to refute the charge, the photo radar cameras, albeit fallible, can claim a stronger case than human recollection [13]. The offender may have forgotten the incident entirely, may not remember event details, or may not have been at all cognizant of their error. Inspired by the culpability of this visual record, the Cook's Collage recorded unedited photographs to display recent ingredient additions.

Lastly, I wanted the Cook's Collage as a shared artifact between human and machine to facilitate mutual interpretation of the displayed information rather than the traditional one-directional delivery of one-directional query. I was encouraged by experimental results that suggested sharing visuals while working together on a project significantly facilitated dialog interchange among teammates because sharing context established *common ground* in language [35]. In this way, the Cook's Collage showed images of this and that ingredient to be understood by the user within context rather than identifying specific items (e.g., sugar, salt). I was also inspired by televised sports analysts who explain behaviors by revealing step-by-step actions with visual annotations. In this way, the Cook's Collage differentiated repeated ingredients that looked similar with clear number annotations that increment with each repetition.

3.5 Design Contribution: Deja Vu Displays

The American Heritage dictionary [4] defined the word *deja vu* that originated from the French word *deja* meaning *already* and *vu* meaning *seen* as

1. an impression of having seen or experienced something before; the experience of thinking that a new situation had occurred before
2. a dull familiarity and monotony.

The negative uncertainty from the deja vu experience epitomizes the memory dilemma I seek to investigate. Confusion can arise *within* an individual between having performed an action vs. intending (or imagining) to perform the action. Disagreements can arise *among* individuals recounting completed vs. uncompleted tasks. Any interpretation and selective pruning from "smart" technology of an otherwise overflowing history archive are still considerably unreliable, and users may not trust the "reality" of automated video diary [31]. On the positive side, the sense of familiarity from the deja vu experience motivated my heavy reliance of user context in designing the Cook's Collage.

- *D istributing Cognition* of
- *E vanescent Recent Activity* by
- *J uxtaposing Display* of
- *A lready Seen Information* as
- *V ideo*
- *U nits*

I used the term *deja vu* to embody my overriding design goal and as an acronym (see above) to contribute as a conceptual framework to inspire further designs of visual summaries augmenting memory recall of repetitive actions.

3.5.1 Distributed Cognition

Distributed cognition is achieved by dispersing internally stored information externally into the physical environment. The determining factor in this design concept is to decide which internal information is of importance to externalize. In the Cook's Collage, I directly applied this principle by capturing transient information from memory for actions (i.e., which ingredient was added how many times) that would be ideally remembered internally and by representing that information (i.e., photographed ingredients with number annotations) externally in a kitchen screen display. The Cook's Collage illustrated how distributed cognition can be a powerful approach in providing recourse from memory slips by transforming memory recall from internal access within the brain into external recognition of memory triggers.

3.5.2 Evanescence of Recent Activity

Evanescence of recent activity is achieved by sustaining a manageable subset of constantly growing information rather than retaining the entire history of increasingly obsolete records. The determining factor in this design concept is deciding the amount of information that is of relevant importance for the user at any given time within the ongoing activity but that also is of manageable use. In the Cook's Collage, the visual summary retained an evanescence of recent activity by continually transitioning old ingredient images positioned in the top-left corner off the display to make room for the new ingredient. By selecting recipes with ingredients *more than* the manageable display space of the Cook's Collage, I learned that cooks rarely asked for the entire ingredient summary, but they frequently queried for the most recent ingredient; thereby, suggesting value for the evanescence of recent activity.

3.5.3 Juxtaposition of Displayed Information

The juxtaposition of displayed information helps to *compose* and to *isolate* the units of information so that correct *review* of the recorded narrative is *readily* accessible for the *user*. The determining factor in this design concept is to decide which memory association (i.e., temporal, spatial, semantic) can be used effectively and efficiently in *retrieving* the desired information within the situational context. In the Cook's Collage, I juxtaposed the six most recent actions along a film reel motif to suggest a time sequence metaphor, lined the horizontal film reel borders to suggest horizontal reading, and highlighted the bottom-right image to suggests it as most important (i.e., most recent). This temporal sequencing of displayed information illustrated how facilitating and expediting a frequently utilized memory strategy of mentally retracing recent actions within a given area can be a powerful support mechanism when confronted with the memory question, "What was I *just* doing *here*?."

3.5.4 Already Seen Information

I termed *already* to mean retrospective memory involving the past, and I termed *seen information* to mean memory for actions involving information from physically (i.e., visually seen except for visually-challenged individuals) performed actions. In the Cook's Collage, I applied this principle literally by mirroring the cook's visual information with unedited photographs of their ingredient additions and figuratively by annotating the cook's repetitive motions with numbers on the photographs. The wide gap between participating cooks vs. general viewers in reconstructing memory for actions from the Cook's Collage display pointed to how pivotal this design parameter was in representing already seen information.

3.5.5 Video

As a visual, the video medium is rich in content and context, and reviewing self-captured video seems to invoke an emotional and contextual identification akin to a deja vu response of the captured personal experience. The determining factors in this design paramater include viewing angles and imaging processing. In the Cook's Collage, I used overlapping video footage at opposite viewing angles to minimize occlusion and maximize coverage. I maximally edited the *units* of video stream (explained below), but I minimally edited the image of video content (i.e., lighting optimization) to maximize the deja vu response of dull familiarity. The Cook's Collage illustrated how video can be a powerful medium in supporting memory recall of repetitive actions.

3.5.6 Units

Just as an activity can be divided into tasks, video footage can be parceled into segments. The determining factors in segmenting units of video for a visual summary are deciding which chunks of memory for actions is of importance for memory recall and how much cost is consequentially required of the user to review these units. For the Cook's Collage, I defined each ingredient addition as a unit of cooking activity useful in recalling correctly, and I displayed each ingredient addition as a photographed image (i.e., a keyframe of video) to minimize cost of reviewing time for the user. The Cook's Collage demonstrated video images as units in summarizing activity.

3.5.7 General Applicability

Design parameters of deja vu displays can create a *variety* of visual summaries to augment memory for actions. This thesis contributes the Cook's Collage as an in-depth example supporting everyday home cooking. I developed *Memory Mirror* to record medicine compliance for caretaker(s) to review (and confer) [106]. Upon previewing the Cook's Collage, older adults suggested a deja vu display for a step-by-step review during home maintenance projects, and parents of newborn babies requested help for their sleep-deprived memory recall of frequent bottle feedings and diaper changes.

These opportunities for further deja vu displays point to the generality of the Cook's Collage display design. Albeit individual differences in uses of the Cook's Collage (reported in Chapter 6), there were negligible variability in user preferences to the choices of visual features. In designing the Cook's Collage, I deliberately targeted the user profile not to include visually impaired individuals requiring non-visual aids, novice cooks or cognitively-impaired individuals requiring step-by-step instructions, and non-cooks requiring situational context from the physical surroundings. Within this user group, I did not intentionally cater design features *specific to* older adults since aging is not the only cause for memory slips. Rather, I chose universal design that fortunately resulted in design features *friendly to* older adults. For example, older adults could avoid the social stigma and self-denial of memory ability decline specific to aging by gradually accepting, albeit not formally admitting to, memory support from the Cook's Collage which paralleled the general pattern of adoption I envisioned for everyone. Similarly, *general* benefits from the design principle of distributed cognition are inherently applied by definition into physical mechanisms of environmental support known to benefit older adults *in particular*. However, I learned that older adults (and sequentially-oriented task managers) are specifically prone to a behavioral condition termed *tunnel vision* of physically putting their heads down into the current task to visually limit their attention focus from distractions, interruptions, and concurrent activity [24]. This tunnel vision behavior, heavily stressed with multitasking and interruptions, increased the need for memory assistance, but the same tunnel vision in attention focus hampered opportunities to use the Cook's Collage. The resulting outstanding design paradox illustrated how extenuating conditions unfortunately can shift some older adults outside my defined user profile for *passive* deja vu displays because these individuals could receive better memory support from *pro-active* step-by-step instructions.

3.6 Summary

In this chapter, I detailed the display features of the Cook's Collage, defended my design choices based on user feedback from earlier prototype iterations and on similar design approaches from previous work, and introduced a conceptual framework for further designs of visual summaries to augment memory recall of repetitive actions.

Beyond these design contributions, the purpose of this chapter was to establish the design components of the Cook's Collage as the testing apparatus to evaluate my thesis claims. That is, I designed the Cook's Collage to enable *user interaction (with accurate memory support to be established in Chapter 4) that complements and supplements rather than interferes with memory practices, activity constraints, and environmental surroundings* so that I can investigate whether this design *can effectively augment memory recall.* Also, I presented in this chapter the tale of two perspectives (i.e., users vs. non-users) in support of the thesis statement that "visually summarizing activities by capturing items used within the activity in the same physical surroundings can provide sufficient context in recalling memory for actions." I will continue these design discussions throughout this document as needed to explicate other aspects of this work.

CHAPTER IV

RECOGNIZING REPETITIVE ACTIONS

In this chapter, I detail the software infrastructure and visual interfaces for the wizard of Oz simulation, document my implementation rationale, and establish the technical component of my thesis questions. The research contributions of this chapter are lessons learned in honing monitoring capabilities for the wizard of Oz system; that iterative experimentation of various sensing components demonstrated to be beneficial, detrimental, or superfluous (i.e., *how* to be smart). The chapter begins by defining my imposed restrictions and subsequent support for the wizard of Oz. From an example (see Figure 5 in Chapter 3), I describe monitoring procedures the wizard of Oz followed in generating the Cook's Collage sequence; thereby, illustrating what the wizard of Oz could and could not do. Then, I review my performance *as* the wizard of Oz and comment about consequential effects on the user experience. I reflect on key engineering decisions made from my direct experiences as the wizard of Oz and reinforced by similar implementation. With the success of this wizard of Oz as a viable simulation of the Cook's Collage that enabled interactive user experiences with the memory aid while cooking, I contribute its contextualized monitoring requirements as a sufficient framework (i.e., what is smart *enough*) for everyday monitoring of repetitive actions. I end this chapter by previewing how these simulation components attributed to my underlying thesis questions for effective implementation.

4.1 Restricting the wizard of Oz

I intentionally isolated the wizard of Oz physically from the cook and the kitchen to regulate the availability of various inputs. As Figure 8a shows, I was stationed in an adjacent room to the kitchen with an adjoining wall to the cook's work space.

Although separated visually, the dividing wall yielded to clearly audible clamoring of jar containers and other kitchen activity. Not being able to restrict audio as an input modality for the wizard of Oz, I kept the room door ajar so I could listen fully to ambient noises from the kitchen that resounded through the open floor plan of the house. In contrast to this free flow of audio, I restricted visual sensing to only the visual interfaces (see Figure 8b) feeding from two video cameras positioned in the kitchen. Beyond these provided software tools, I did not provide a copy of the current recipe as reference material nor any other monitoring aids (e.g., notepad, checklist) to control information and capability supplied to the wizard of Oz. As the wizard of Oz, I did not require any further resources in simulating the Cook's Collage.

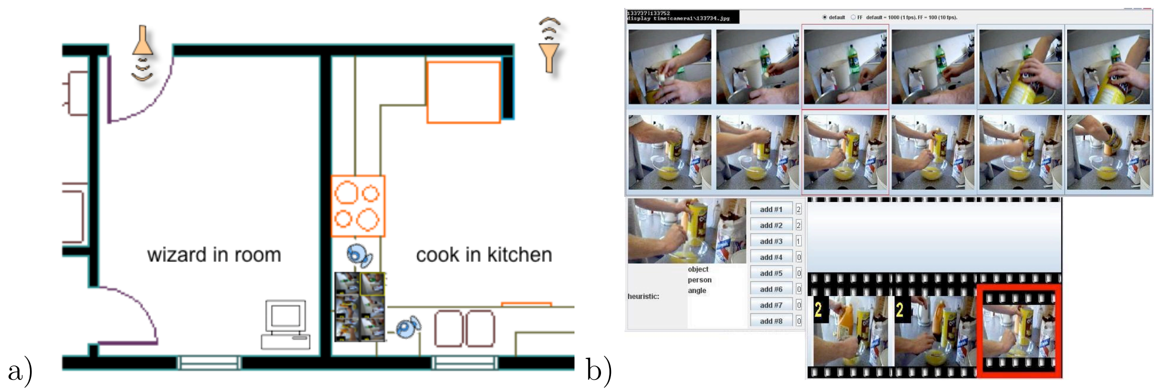


Figure 8: Isolating wizard of Oz in a) adjacent room with b) visual interface

Within these a priori restrictions, the wizard of Oz (i.e., human operator) was *able* to determine for the Cook's Collage *while* the cook was the kitchen:

1. Whether a specified action (i.e., ingredient addition) occurred among otherwise negligible activity;
2. Whether the action was the same as previously marked actions (i.e., repeating ingredient) or a different and new action;
3. Whether the started action has completed; and
4. Which photograph represented the action most clearly.

4.1.1 Sufficiency Testbed

In restricting the ability and responsibility of the wizard of Oz, I tested for sufficient engineering of user requirements. How smart is enough to be usable and useful? How accurate is enough? How fast is enough? That is, what *minimal* resources can the wizard of Oz provide to the cook as *sufficient* context in recalling memory for actions? My goal for the wizard of Oz was to support a wide *range* of performance levels for users to *calibrate* and *settle* upon the tolerance levels regarding system limitations.

In contrast to the majority of wizard of Oz prototypes that simulated ideal or foreseeable system requirements as the predominant motivation for implementing the wizard of Oz technique [26] and for utilizing wizard of Oz toolkits (e.g., [69, 30, 21, 62]), only a few other feasibility tests have recently explored thresholds for sufficient system requirements. Fogarty and colleagues employed wizard of Oz simulations of simple sensors as a testbed array in *selecting* which monitoring features effectively predicted human interruptibility [49]. The "memory glasses" system reported use cases in which *imperfect* information presented as subliminal cues for just-in-time memory support did counterintuitively *improve* performance [27]. Similarly, I used the wizard of Oz simulation as a testbed to determine which input modes and control mechanisms produced memory cues at a pace and accuracy that, albeit imperfect, could effectively aid the user's memory recall.

4.2 Software Infrastructure

Figure 9 presents an overview of the software infrastructure for the Cook's Collage. I built the entire software infrastructure after initially using available prototyping toolkits for capture and access applications (e.g., [110]). I decided that a basic *producer-consumer* flow model was sufficient to circulate and archive photographs. The kitchen cameras captured (i.e., produced) photographs constantly (e.g., 1 frame per second) for the wizard of Oz to monitor (i.e., consume) via visual interfaces. In turn, the wizard of Oz selected a subset of photographs that represented added ingredients for the Cook's Collage display in the kitchen to update (i.e., consume) as the ongoing summary. To minimize threading bottlenecks in frequently transferring photographs (i.e., .jpg files 10k in size) over a local area network in real-time, I chose Java Media Framework for its robust synchronization mechanisms within each image object. However, maintaining a consistent capturing feed caused one or two photographs to be dropped by Java periodically; thereby, appearing as empty placeholders within the visual interface. I decided that simple file sharing was sufficient to establish the shared database. Each camera created a folder to populate with .jpg files, and each file was referenced by its timestamp; therefore, I synchronized photographs across all kitchen cameras simply by accessing files across the same timestamps. Beyond basic circulation, the producer-consumer model allowed me to support two key infrastructural features as follows.

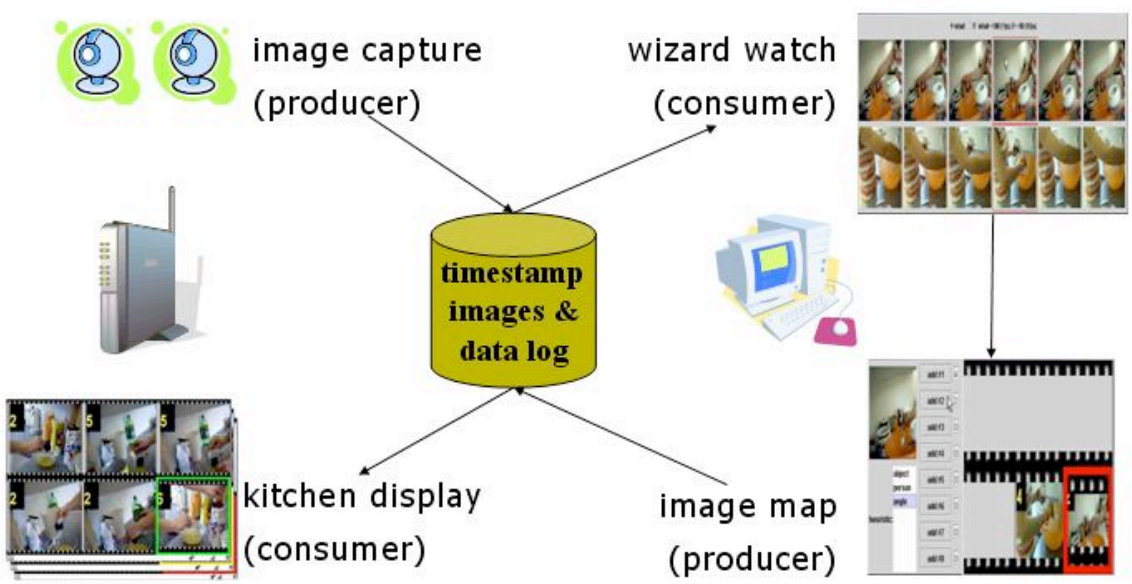


Figure 9: Producer-consumer flow model for the Cook's Collage system

4.2.1 Automated Archive

Levering the producer-consumer model, the software infrastructure automatically archived every photograph captured from the kitchen cameras along with every photograph hand-picked from the wizard of Oz. It maintained an event log that associated the selected photograph to the represented ingredient addition and its running count. Additionally, I collected audio recording and video footage as part of study procedures reported in Chapter 6. Because automated activity monitoring can only become feasible given training data, I decided to archive all inputs supplied to the wizard of Oz as training data for experts in computational perception to draw their own conclusions from.

4.2.2 Dual Clock

To alleviate competing responsibilities for the wizard of Oz to be fast and accurate in monitoring repetitive actions, I implemented a dual clock setting in moderating audio and visual feeds. I established the current *real-time* by synchronizing system clocks between the wizard of Oz's computer and the Cook's Collage display. I added a *pseudo-time* to represent the running time for the visual interface that the wizard of Oz could speed up and slow down at will whereas the running time for the Cook's Collage display and ambient noises from the kitchen remained unabated. I reflected this time discrepancy visually for the cook as the *tortoise-and-hare* feature (see Chapter 3) across the bottom of the Cook's Collage and for the wizard of Oz as ticker tape of both timestamps (in Figure 13). This dual clock setting permitted the human attention required to *recognize* each ingredient addition at a human pace without interfering with the accuracy of subsequent monitoring.

4.3 Visual Interfaces

Albeit the only visual input provided for the wizard of Oz, these visual interfaces worked within the software infrastructure detailed in the previous section and in concert with audio input detailed in the ensuing section so that I could monitor and annotate salient actions (in this case, ingredient additions).

4.3.1 Monitoring Activity

I visually monitored activity of the cook from the kitchen with a visual interface that contained sequenced photographs as shown in Figure 10. The top row of photographs corresponded to the camera positioned in the left corner of the countertop space; thereby, capturing fully right-handed additions of ingredients, and the bottom row of photographs corresponded to the camera positioned in the right corner of the countertop space; thereby, capturing fully left-handed additions of ingredients. Every photograph was labeled with a timestamp, so photographs in a column corresponded to the same point in time. The cameras automatically adjusted for lighting from the overhead kitchen lights and for sunlight from the kitchen sink window.

Figure 10: Stop-action photographs sequenced from left to right at one frame per second from right-sided camera in bottom reel and left-sided camera in top reel of cook grabbing the orange juice container while holding a measuring cup in his other hand, pouring orange juice from the container into the measuring cup, and emptying orange juice from measuring cup into the mixing bowl

New photographs appeared at the rightmost end of the interface. Photographs shuffled left one position to make room for the next incoming photographs, and the photographs at the leftmost end of the interface shuffled left off the screen as shown between Figure 11-12. This procession of photographs continued at the default rate of one frame per second.

Figure 11: Sequenced photographs one second before Figure 12

Figure 12: Sequenced photographs one second after Figure 11

I was able to increase the video's default streaming rate of one frame per second to a fast-forwarded speed of ten frames per second by toggling the buttons towards the top of the visual interface. By fast-forwarding through photographs depicting negligible kitchen activity (e.g., mixing, cleaning, attending to interruptions or other tasks), I was able to offset my accrued time delays from earlier pausing of sequenced

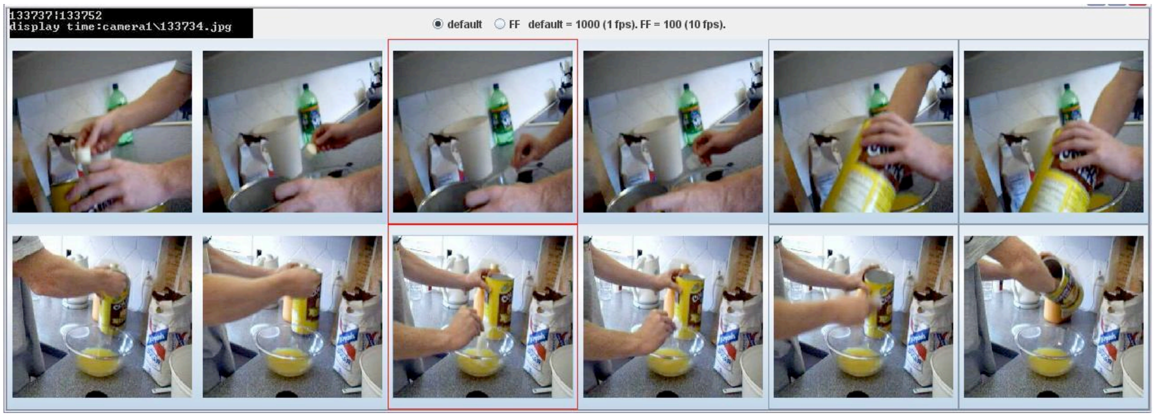


Figure 13: Sequenced photographs of cook reaching into powder container, adding a scoop of powder into the mixing bowl, and reaching again into the powder container reveal visual ambiguity between repetitive actions that the thin red lines bordering the third photographs from the left end delineate as the wizard of Oz's selection. The black ticker tape reflects the dual clock setting and logs timestamp of photographs posted to the Cook's Collage.

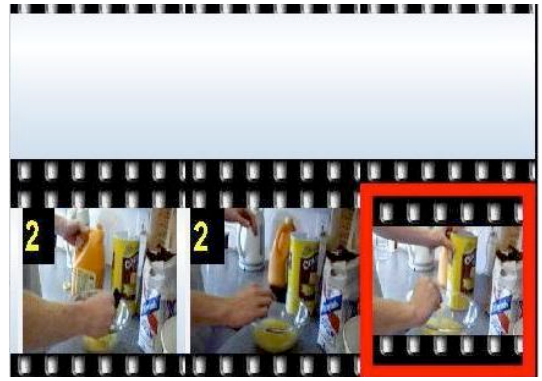
photographs in annotating actions (explained in the next section). I referenced accrued time delays via a ticker tape representing the dual clock setting (described in the previous section) along with logged timestamps of photographs posted to the Cook's Collage. Also, I was able to realize when ongoing kitchen noises no longer matched with the sequenced photographs.

4.3.2 Annotating Action

I identified each ingredient addition using a dialog interface in Figure 14a alongside a miniature version of the Cook's Collage display (without the tortoise-and-hare feature) in Figure 14b. Upon confirming that an ingredient was added, I selected its representative photograph with a mouse click on one of the incoming photographs (see Figure 13); thereby, causing thin red lines around the column of the selected photograph to demarcate the action from preceding and proceeding repetitions of the same action.

Also at this point in time, the procession of incoming photographs paused; thereby, permitting me *time* to complete the task of associating the action represented in my

a)



b)

Figure 14: Upon selecting among the photograph sequence in Figure 13, the photograph is a) associated as the third ingredient by visually matching with b) the third previously added ingredient photograph on the Cook's Collage

chosen photograph *before* monitoring for the next ingredient addition. A dialog interface (see Figure 14a) appeared; thereby, permitting me to associate the represented action with a mouse click on one of the generically sequenced ingredient buttons upon visually matching the selected photograph with the accumulating photographs of recently added ingredients on the Cook's Collage display in Figure 14b. With the particular photographs in Figure 14 as an example, I associated the selected photograph to represent the third ingredient based on a visually similar photograph on the Cook's Collage display as the third photographed ingredient (i.e., bottom-right corner). If I selected the photograph in error, I could click to close the dialog interface without identifying the photograph as an added ingredient; thereby, canceling the photograph selection. Optionally, I was able to document a selection heuristic (e.g., object, angle) for the selected photograph. Upon completing the ingredient annotation, the procession of sequenced photographs resumed while maintaining the thin red lines highlighting the previously selected photograph; thereby, providing a point in time to *continue* monitoring from.

4.4 Performance Results

In this section, I discuss on how *well* I was able to simulate the Cook's Collage display for busied cooks in the kitchen. With Figure 5 from Chapter 3 demonstrating what the cook saw of the Cook's Collage display in the kitchen, I illustrate from the wizard of Oz's perspective how I *envisioned* utilizing provided inputs and system features in monitoring and recognizing corresponding ingredient additions; thereby, demonstrating what the wizard of Oz could and could not do in simulating the Cook's Collage display. Then, I *quantitatively* report results (corresponding with user performance results of assigned recipes in Chapter 6) of my identification accuracy and processing speed as the wizard of Oz, and I *qualitatively* identify extenuating circumstances for my inaccuracy and delay. Lastly, I mention a few minimal ways the cook was advised to assist the monitoring system to improve greatly the monitoring accuracy of the Cook's Collage system.

4.4.1 Example Simulation Sequence

As the user began the cooking session in the kitchen, I listened for tell-tale cooking sounds from the kitchen and watched for the cook's hands adding ingredients into the mixing bowl among the incoming captured photographs. Also on my monitoring screen, I referenced a miniature copy of the Cook's Collage mirroring the actual Cook's Collage display in the kitchen and a ticker tape reflecting the running times between the Cook's Collage display and my visual interface of incoming captured photographs. Starting the monitoring session with a blank Cook's Collage display and synchronized running times, I watched the sequenced photographs of the cook as he reached for the first ingredient container (e.g., orange juice bottle) with his left hand, unscrewed the container lid, grabbed the measuring cup with his other hand, and poured the contents from the ingredient container into the measuring cup. I recognized the progression of these physical actions based on the human experience of pouring oneself a drink. Then, I watched the stop-action sequence of photographs as he poured the contents of the measuring cup into the mixing bowl. This specific action I identified as an ingredient addition that has completed; thereby, transitioning my monitoring of the general kitchen activity into my annotating of the particular action. I quickly scanned the photograph procession for a photograph exhibiting the added ingredient. In response, the system highlighted my photograph selection with thin red lines, recorded the timestamp on the ticker tape window, paused the procession of sequenced photographs, and provided a dialog interface to annotate the photograph. Visually comparing with the initially blank Cook's Collage display (see Figure 5a), I identified this new action as the first ingredient by clicking on the *add #1* button. Although the captured photographs clearly identified the commercially labelled ingredient container as orange juice based on my human experience (i.e., using the same product), I was not obligated in this wizard of Oz system to identify the ingredient by its *particular* name but only by its *relative* association among the other ingredients. Upon which my selected photograph was added to the Cook's Collage display (see 5b), and the procession of incoming photographs resumed with my processing time of one second reflected in the ticker tape.

Continuing to watch the sequenced photographs, I recognized the cook again pouring the contents of the ingredient container into the measuring cup and again pouring the contents of the measuring cup into the mixing bowl. So, I quickly clicked on another photograph for this repeated action with the previously selected photographed still highlighted on the monitoring interface as graphic demarcation between the visually similar photographed sequences. With more preparation time, I chose a photograph from the right-sided camera that captured a clear view of the cook's hand over the mixing bowl, with the ingredient contents in the bowl, and with the ingredient container immediately behind the bowl. Upon annotating the photograph by clicking the *add #1* button again, the wizard of Oz system updated the Cook's Collage display (see Figure 5c). The feed of captured photographs resumed with my processing time of two seconds reflected in the ticker tape as accumulated total of three seconds. I realized the delay upon hearing water running from the sink faucet in the kitchen while my monitoring interface still showed the cook closing up the first ingredient container (e.g., orange juice bottle). I quickly remedied this time discrepancy by clicking on the fast-forward button. Once the ticker tape reflected identical timestamps, I returned the photograph feed to the default speed of one frame per second. The cook was pouring an ingredient that I could not *identify* because he was not holding any ingredient container in his other hand as with the previous ingredient. However, I could *recognize* that it was a *different* ingredient than his prior ingredient(s) shown on the Cook's Collage thus far, so I associated it as the *#2* ingredient. With the Cook's Collage updated (see Fig 5d), I continued this procedure for every addition of every ingredient relying on my human interpretation to piece together visual and audio components in determining four basic characteristics of repetitive actions within everyday cooking.

4.4.2 Recognition Accuracy

While monitoring cooking activity with the wizard of Oz prototype, I occasionally had difficulty determining whether the cook had *completed* an ingredient addition. I over-counted (i.e., false positive) an ingredient if I misinterpreted the cook's repeated attempts of the same ingredient addition, usually when the ingredient (e.g., orange, pineapple, sherbet) was stuck onto the scooper utensil or when the cook paused to double-check recipe measurements (e.g., of powder, vanilla). I under-counted (i.e., false negative) an ingredient addition if I was too slow in selecting an incoming photograph showing the ingredient being added before it shuffled off the visual interface. Also, the cook's hand motions in pouring small amounts of an ingredient (i.e., vanilla) were too subtle and required diligent visual scrutiny or were too fast for the sparse capturing rate (i.e., one frame per second) and required a higher frame rate. Remote ingredient containers (i.e., water from the sink) initially prompted some cooks to move the mixing bowl out of camera view, and ingredient containers obstructed or outside of camera view increased the recognition difficulty from my isolated viewing angle in determining whether the added contents were from new or repeated ingredients.

I defined recognition accuracy as absence of monitoring errors. With event logs from the automated archival system detailed in the previous section, I compared ingredient additions I *perceived* the cook to have performed via the wizard of Oz simulation in comparison with video recordings of *actual* ingredient additions. For each ingredient that the cook added, the wizard of Oz was responsible for identifying the *same* number of repetitions. Any fewer or any more than what the cook actually added constituted as a monitoring error. For example, *-1 flour* denoted that I tracked one fewer ingredient addition of flour than the cook had actually added. Similarly, *+1 soda* denoted that I tracked one more ingredient addition of soda than the cook had actually added.

Table 1 catalogs all monitoring errors I committed as the wizard of Oz from the Repeated-Use Study. Although detailed in Chapter 6, it is important to note here that 696 ingredients were to be added under four differing trial conditions across four sessions from six participating cooks. Out of the 688 ingredients actually added by participating cooks, I committed 69 monitoring errors as the wizard of Oz; thereby, establishing my error rate at 10% (i.e., recognition accuracy at 90%).

Table 1 marks 15 monitoring errors (in capitalized font) out of the 69 total as having negatively affected the cook's ingredient accuracy. For example, *-1 WATER* denoted that the Cook's Collage tracked one fewer ingredient addition of water; thereby, prompting the cook to compensate by adding one extra count of water than the required recipe count. That is, the cook's ingredient error occurred after unwittingly

Table 1: Catalog of Recognition Errors

Trial	Session 1	Session 2	Session 3	Session 4
Punch recipe only (P)	-1 powder +2 powder +1 soda -1 orange	-1 powder -1 water		
Punch recipe and Multitasking (PS)	-3 powder +1 powder -1 water -1 WATER -1 SODA +1 sugar	-1 powder -1 powder -1 WATER +1 pineapple	-1 powder -3 powder -1 WATER -1 soda -1 soda -1 ORANGE +1 PINEAPPLE +1 SHERBET	-1 water -3 water -1 soda +1 orange -2 orange +1 pineapple -2 pineapple
Punch recipe Multitasking, and Interruptions (PSI)	+1 powder -1 powder -2 POWDER -1 WATER -1 SODA -1 orange -2 pineapple	+1 POWDER -1 powder -1 powder -1 soda +1 soda	-2 powder -2 pineapple	+3 POWDER -2 powder -2 WATER -2 WATER -1 soda +1 pineapple +1 PINEAPPLE -1 sugar
Cookie recipe Multitasking, and Interruptions (CSI)	-2 flour -1 vanilla -2 vanilla +1 vanilla	-1 vanilla -1 vanilla -2 vanilla +1 sugar +1 b.sugar	-1 vanilla -1 vanilla	-1 flour -1 vanilla -2 vanilla +1 vanilla -2 baking soda

using the inaccurate memory aid; thereby, identifying these *consequential* monitoring errors (i.e., of negatively affecting the cook's ingredient accuracy) at a rate at 2% (i.e., effectively 98% recognition rate).

The remaining 54 out of 69 (i.e., 78%) monitoring errors did not directly influence the cook's ingredient errors because the cook either coincidentally did not look at the Cook's Collage display or purposefully ignored the erroneous information; thereby, not using the inaccurate memory aid in either case. A closer breakdown of the 40 inconsequential errors from the punch recipe (i.e., Trials P, PS, PSI) revealed a composition of 14 recognition errors for the powder ingredient that the cooks typically added *first* and *quickly* before being distracted. As a result, these cooks had no memory need that precipitated using the Cook's Collage and they were confident of their accuracy. Similarly, a closer breakdown of the 16 inconsequential errors from the cookie recipe (i.e., Trial CSI) consisted of 11 recognition errors for the vanilla ingredient. All cooks were cautioned upfront about camera tracking limitations of quick and subtle motions (as I discuss shortly); thereby, *preparing* them to decide under which circumstances and for which ingredients to trust the recognition accuracy and which not to.

4.4.3 Processing Time

Monitoring cooking activity with the visual interfaces, I occasionally had difficulty annotating the ingredient addition in a timely period. With incoming photographs pausing for each ingredient identification, I incurred at least one-half second delay for every ingredient addition. I was able to resynchronize the streaming photographs with the ambient sounds from the kitchen but only *between* ingredients not to risk fast-forwarding *past* any ingredient additions. Therefore, processing delays accrued when the cook added many amounts in quick succession (e.g., water, vanilla). The tortoise-and-hare feature on the Cook's Collage archived timestamps of the time discrepancy for every ingredient photograph displayed. This event history (from the Repeated-Use Study in Chapter 6) logged my processing delays in simulating the Cook's Collage for the cook to use in real-time to be

- most frequent (i.e., mode) of 1 second,
- average of 3 seconds; and
- maximum of 19 seconds.

4.4.4 Affected User Experience

Because the Cook's Collage did not restrict the cook into following any scripted sequence or procedure nor required the cook to use the offered memory assistance, the cook was in complete control of the user experience. If the cook chose not to use the Cook's Collage, the cook was free to add ingredients anywhere in the kitchen using any manner desired. However, if the cook chose to use the Cook's Collage, a few minor adjustments were advised of the cook in return for maximal benefit from the memory aid.

The cook was asked to leave the mixing bowl on the corner countertop to be in full view of the positioned cameras for the monitoring system; thereby, enabling the Cook's Collage to capture photographs of ingredient additions. It is important to note that kitchen countertops are purposefully built as physical work space for food and drink preparations and that most ingredient containers are easily moveable. Thus, this restricted location did not affect the cooking experience except when adding water from the sink at a considerable distance away from the mixing bowl.

The cook was asked to refrain from adding repeated amounts of an ingredient too quickly in succession to improve the counting accuracy from the monitoring system and to improve picture clarity of the Cook's Collage. My cameras' archival rate of one frame per second for the wizard of Oz produced sufficiently sequenced photographs for most added ingredients with the exception of particular ingredients (e.g., vanilla, powder). At considerably fewer frames per second than high-speed cameras that capture motions of water droplets, my cameras captured thirty frames per second; thereby, producing motion blur that obfuscated the photographed ingredient in most of the photographs. Some cooks adapted coping techniques to work within the limitations (i.e., inaccuracy, delay) of the Cook's Collage as detailed in Chapter 6.

Related examples of recognition systems receiving minor assistance from the user in return for maximal benefit include red-eye reduction software that produce better results when users designate key areas in photographs and language translation of photographed signs when users crop out extraneous areas [116]. As with the Cook's

Collage, the user was not *required* to adhere to restrictions, but their *minimal* investment yielded *maximal* return from the recognition system.

4.5 Lessons Learned

As the human operator of the wizard of Oz simulation for more than 226 cooking trials in the Aware Home kitchen laboratory and as the software developer of the wizard of Oz system for three prototype iterations, I gained insightful experiences that greatly informed my decisions in key engineering features. Albeit as just *one* wizard of Oz, I describe lessons learned in monitoring repetitive actions in everyday cooking and recommend techniques I found to be successful in contrast to earlier techniques I found to be not as successful.

4.5.1 Observation of Repetitive Actions

Mentioned earlier as extenuating circumstances that contributed to monitoring errors as the wizard of Oz, I observed the many unpredictable improvisations people do while cooking in the home. At times, the cooks quickly rushed through their motions. Other times, they paused to reconsider their actions. In the middle of adding an ingredient, some double-checked recipe details in comparison with the held measuring utensil and their recollection of their cooking progress. These self-imposed interruptions created rapid back-and-forth motions of stopping and restarting, introducing unintentional ambiguity in the repetition. Some cook experienced physical difficulty while adding an ingredient. For example, the ice cream scooper sometimes did not cleanly release sticky ingredients (e.g., sherbet, frozen concentrate), so a common reaction was for the cook to tap the scooper repeatedly against the mixing bowl until it loosened the ingredient into the bowl.

4.5.2 Audio

As *a* wizard of Oz, I came to rely on audio as an input modality. Ambient noises incidental to cooking activity from the kitchen were audible when the office room door to the wizard was left ajar. With the door closed, I could not decipher sounds from the kitchen. Through earlier system testing with and without audio, I discovered that my monitoring accuracy and confidence improved greatly with audio provided.

I found audio to be useful in *segmenting* among ingredients because the additions of one ingredient were discernibly different than for another ingredient. Poured ice sounded different than poured water. Poured chocolate chips sounded different than poured flour. The sounds of opening jars were uniquely different than opening plastic bags which sound different than opening soda bottles. Tapping cups sounded different than tapping spoons. Many cooks tapped measuring cups and spoons onto the top of the mixing bowl to ensure proper emptying of the contents, so I used these sounds of added ingredients (for non-sticky ingredients at least) to signal the *completion* of an ingredient addition. The glass mixing bowl amplified sounds of ingredients being added, but plastic bowls also sufficiently carried sounds of added ingredients. The hardwood floors of the kitchen helped to relay the acoustics. In a different domain (e.g., wood working) from cooking, Starner and colleagues similarly found audio monitoring useful in distinguishing between task segments (e.g., sawing, hammering, drilling) [111].

4.5.3 Video

Figure 15 shows video cameras strategically positioned around the corner countertop cooking area that sufficiently satisfied design goals of minimizing privacy concerns from being unobtrusively visible to the cook, maximizing identifiable details of the ingredient added, possibly capturing the motion of adding ingredients, minimizing object occlusions, and minimizing extraneous details of the cook. Through camera testing, one or more cameras were blocked so that I could compare the added value. I discovered that I used photographs from only two out of the four available cameras. The left-most camera sufficiently captured right-handed ingredient additions, and the right-most camera sufficiently captured left-handed ingredient additions. Both cameras had unobstructed viewing angles of the ingredient being added (with slight motion blur to accentuate the action), and the viewing angles were wide enough to capture the container of the current ingredient for most cases. The two middle cameras did not have the wide viewing angle (or fish-eye distortion [99]) to capture the ingredient container, and they captured extraneous details of the cook's body. Moreover, I discovered that the most representative photographs for ingredient additions were those photographs captured from the side cameras of the ingredient visibly being poured from the container into the mixing bowl. An additional camera positioned from the kitchen ceiling above the designated corner countertop (in Figure 15), provided a top-down view of the cook's location in the kitchen. However, I hardly referenced this video feed because the ambient sounds from the kitchen served the same purpose with more efficiency than the overhead camera.

As *a* wizard of Oz, I struggled with just straightforwardly watching video in monitoring for repetitive actions. In earlier system testing of only streaming video (i.e., without corresponding audio), I realized that hand movements in everyday cooking (i.e., skilled activity) are quick and short in action; thereby, requiring *constant* attention not to miss an ingredient addition. However, counting repeated ingredient additions can be frustratingly monotonous for a human operator. Additionally, I discovered the inherent visual *ambiguity* of repeated actions. Video depicting a scoop of an ingredient being added looked almost identical to video showing another scoop of the same ingredient being added. Moreover, video depicting a successful ingredient addition to the mixing bowl looked almost identical to an unsuccessful ingredient addition still stuck to the measuring utensil. In all instances, *careful* attention to detail

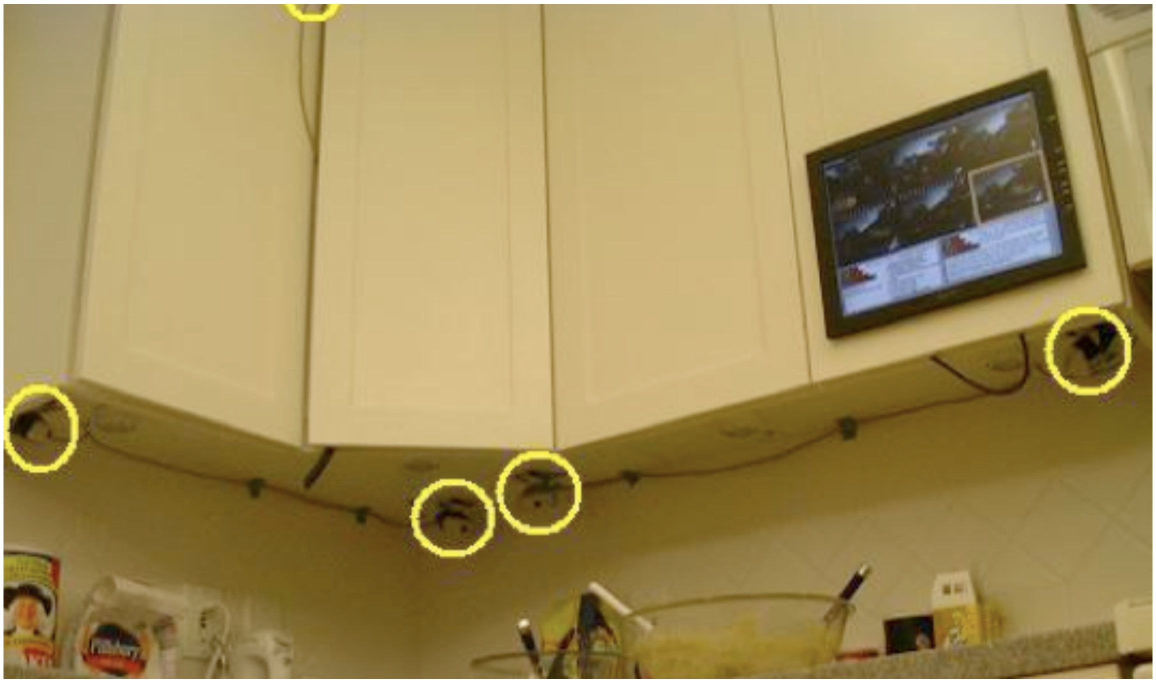


Figure 15: Five camera angles to test coverage of corner countertop space

was required in video monitoring. Lastly, streaming video across *time* did not allow for photograph selection of the transpired ingredient addition. For these reasons, I devised the visual interface to sequence photographs across *space*.

4.5.4 Refinement of Visual Interface

In selecting ingredient photographs captured from cameras, I improved upon the visual interfaces by incrementally introducing minor but transformative features to maximize accuracy and proficiency in my monitoring of repetitive actions. Through repeated testing, I discovered that six stop-motion photographs per camera row sufficiently captured the *entire* sequence for each ingredient addition. Some ingredient additions required fewer photographs; thereby, allowing for preceding and subsequent action sequences. Paramount in the procession of photographs was the *progression* of an action sequence for me to follow its pacing and flow reminiscent of stop-action animation with the physical dynamics of a motion artificially reviewed as a series of still frames. In watching this stop-action animation across space, I could *chunk* action sequences together; thereby, teasing apart one ingredient addition from the next repetition. Learning from cooks who did stop, restart, and interrupt themselves arbitrarily, I learned not to anticipate but to recognize characteristics indicating the beginning, middle, and ending phases within an action sequence. This inclusive display facilitated following an action until its completion rather than prematurely predicting an action; thereby, addressing my most difficult task as the wizard of Oz.

It is important to note that none of the monitoring errors (see Table 1) from the Repeated-Use Study consisted of the wizard of Oz missing an ingredient entirely or mistakenly identifying ingredients; thereby, indicating a strength in annotating actions. Testing of earlier visual interfaces had incurred misidentification of ingredients as well as much slower processing speed. For example, drop-down lists of anticipated recipe ingredients created a multi-step procedure requiring time and precision. Buttons with particular names of ingredients (e.g., orange juice, water) added a visual search similarly requiring time and precision that caused me to inadvertently misidentify ingredients. Another alternative was to employ keyboard short-cuts rather than mouse clicks (i.e., direct manipulation). Paramount for the wizard of Oz in selecting and annotating ingredient photographs was ease and speed of use. With these considerations, I redesigned the interface dialog as shown in Figure 14 by following Fitt's law for short distancing of large buttons [72] for quick annotation. More importantly, user feedback from the Cook's Collage *display* iterations convinced me that I only required relative naming of ingredients if sufficiently grounded in context. Therefore, I added running counters for each generically numbered ingredient button and a miniature Cook's Collage for visual comparison. I believe this redesign of visual features greatly improved annotation of selected ingredient photographs.

I also improved accuracy by pausing the incoming photographed sequence; thereby, allowing the wizard of Oz time and attention to annotate each ingredient addition.

Otherwise, dividing visual attention for the wizard of Oz would result in monitoring errors similar to dividing visual attention for the cooks resulted in ingredient errors as reported in Chapter 6. Lastly, I improved proficiency with the fast-forward option to skim through negligible kitchen activity. Through incremental iterations, I refined the visual interfaces (and the underlying software infrastructure) to optimize accuracy and proficiency for me as the wizard of Oz operator in monitoring and in annotating repetitive actions.

4.5.5 Post-Analysis

In enabling real-time memory support for cooks to interact with in the kitchen, my top priority as the wizard of Oz was minimizing my processing delays. Consequently, I discovered that annotating heuristics for my photograph selections while simulating the Cook's Collage incurred processing delays that were expendable. Therefore, I used a "divide and conquer" approach to separate real-time simulation from post-analysis of heuristics. I achieved this by rebuilding the monitoring system to be also an archival system. However, the automated archiving added additional system delays independent from human processing delays by the wizard of Oz. My goal was to hone my monitoring skills as the wizard of Oz over time from numerous demonstrations so that my resulting selections for the final study (i.e., Repeated-Use Study) can represent as a comparative baseline for computational perception algorithms to replicate and improve upon.

4.5.6 Low-Level Sensors

As *throw away* implementations, I built two fully functional and automated monitoring systems for the Cook's Collage for two simple cooking situations [105, 109]. In Figure 16a, accelerometers instrumented in ingredient containers detected when contents are poured. In Figure 16b, relay switches embedded in the stove knobs detected

a)  b) 

Figure 16: Monitoring systems for the Cook's Collage automated with embedded a) accelerormeters in bottom of ingredient containers and b) contact switch sensors inside stove knobs and photo diode under mock stove burners

when the heat settings were adjusted. Photo diodes placed in specific locations detected when items were removed from storage. I similarly experimented with RFID tags and readers as used in other domestic memory aids [33]. I used the context toolkit [94] to capture photographs only upon triggering these low-level sensors. In general, the economical cost and miniature size of low-level sensors appealed to me as low-barrier means for feasibility testing, but I discovered that their inconclusive inferences and restrictive uses limited exploration of activity monitoring. They required strategic a priori placement to yield meaningful readings and could only detect discrete events among finite states (e.g., on-off). Regardless, I found low-level sensors useful as coarse-level indexing of activity segments, but I did not use any low-level sensors in the wizard of Oz simulation.

4.6 Sufficient Requirements: Contextualized Monitoring

With the Aware Home kitchen laboratory as a testbed for the Cook's Collage, I learned "what was smart enough" by experimenting with shared context between the cook and the monitoring system within their shared physical surroundings. In this section, I define what the wizard of Oz system could and could not do relative to what the user could and could not do with the cooking objects within the kitchen. From user feedback of earlier design prototypes detailed in the previous chapter, I establish the first three system requirements for the Cook's Collage. From case studies in the Repeated-Use Study detailed in the next chapter, I conclude the last two requirements as thresholds for quality of service. All the following system requirements would not be feasible nor sufficient without shared context of the user (i.e., cook), system, (i.e., wizard of Oz), and monitored space (i.e., kitchen).

4.6.1 Recognition as Identification

The wizard of Oz was not able to *identify* ingredient containers specifically by name (e.g., sugar, flour, salt) from a predetermined inventory. Rather, the wizard of Oz could only *recognize* ingredient containers relatively by history of use. That is, I classified ingredient containers as either visually *similar* to previous items or visually *different* (i.e., new). This differentiation was a sufficient system requirement because the cook (i.e., user) was able to *recognize* the photographed ingredient by visually comparing against the physically available ingredients along the corner kitchen countertop. Unlike participating users of the Cook's Collage, non-users without the shared (visual) context of the ingredient containers were not able to *identify* the photographed ingredients of the Cook's Collage.

Similarly reducing object identification to object recognition based on visual comparisons has been implemented successfully in immersive graphical user interfaces [17] and has been demonstrated to be used often and successfully by collaborating coworkers [35].

4.6.2 Repetition as Measurement

The wizard of Oz was not able to *measure* ingredients specifically by weight as other memory devices were able to [33]. The Cook's Collage could not measure volume, mass, etc. common in recipes. Rather, the wizard of Oz could only *count* repeated *actions*. That is, I classified the number of times ingredients were added. This differentiation was a sufficient system requirement because the cook (i.e., user) was able to *convert* the annotated ingredient photographs by physically referencing back to the measurement conversions listed on the recipe provided within the kitchen. Without the shared (physical) recipe, the number of repetitions was open to the user's interpretation.

4.6.3 Status of Speed

The wizard of Oz was able to produce an ingredient photograph on the Cook's Collage as a memory cue for the cook within just one second most of the time. However, the wizard of Oz was not able to uphold this just-in-time speed for highly repetitive amounts. Inconsistent delays (e.g., from three to nineteen seconds) were represented in the tortoise-and-hare timeline on the memory display. This status indicator was a sufficient system requirement because the cook was able to approximate the time delay from the visual reference. Without this indicator of time delay, cooks were not able to anticipate the *inconsistent* and *accumulating* monitoring delays of earlier Cook's Collage implementations.

4.6.4 Comparative Speed

The quality of service from monitoring delays depended on individual differences. As reported in the following chapter, some users found the speed insufficient while others created ways to accommodate for the system limitation. Thus, the speed of the system needed to be compatible with the speed of the user.

It is interesting to note that *none* of the cooks from the Repeated-Use Study commented about extrapolating time delays in using the Cook's Collage. Many reported *waiting* on the tortoise-and-hare timeline before referring to the information presented on the Cook's Collage. In contrast, cooks from my earlier user studies did not have a status indicator visible on the Cook's Collage; therefore, some commented about *having* to estimate time delays.

4.6.5 Comparative and Focused Accuracy

The quality of service for recognition accuracy depended on individual *perception*. My recognition accuracy as the wizard of Oz needed to be more accurate than the cook's own memory recall and/or needed to be 100% accurate on the cook's identified areas of memory need. Areas of no memory concern did not require recognition accuracy because the cook was able to *ignore* the memory aid. This *usage* differentiation led to my system differentiation from 90% overall recognition accuracy to 98% consequential accuracy as the wizard of Oz. Thus, the accuracy of the system needed to be *trusted* by the user. As I report in Chapter 6, baseline accuracy (i.e., before being introduced to the Cook's Collage) of ingredient additions from six participating cooks ranged from 76% to 97% with an average of 86%. Their ingredient accuracy with the Cook's Collage available ranged from 82% to 97% with an average of 90%.

4.7 Summary

In this chapter, I detailed the implementation features of the wizard of Oz simulation for the Cook's Collage. From direction observations of over 226 cooking trials in the Aware Home kitchen laboratory, I discovered how *unpredictable* human behavior is in everyday cooking; thereby, presenting an overarching complication in *recognizing* repetitive actions. On the other hand, I discovered how many people *cooperate* within system limitations in return for *added value* of machine assistance. Using the wizard of Oz as a testbed, I explored ranges of sufficient requirements for a monitoring system to provide memory support in recalling recent repetitive actions. Using the wizard of Oz as a prototyping tool, I explored how to minimize processing time and maximize identification accuracy.

Beyond these feasibility contributions, the purpose of this chapter was to establish the implementation components of the Cook's Collage system as the testing apparatus to produce case study results for the thesis statements. That is, I simulated the Cook's

Collage to enable sufficiently accurate and sufficiently timely memory support. I will continue these system implementation discussions throughout this document as it affected other aspects of this work.

CHAPTER V

EVALUATING MEMORY AUGMENTATION

In this chapter, I document my method rationale for experimental procedures and analysis techniques that became the Repeated-Use Study (presented in the next chapter) by addressing three pivotal challenges in evaluating memory augmentation:

- How to induce or capture memory slips; thereby, establishing the problem;
- How to probe internal memory strategies and implicit coping mechanisms; thereby, understanding the process of recourse; and
- How to qualify meaningful units of measurement; thereby, defining success for the memory aid.

I explain why the above three components were critical for studying memory augmentation but challenging to achieve experimentally. My method decisions were based from conducting two preliminary studies (e.g., Interruptions Study and Dual Task Study documented in the appendices), reviewing experimental studies of non-technical memory aids, and continually consulting with experienced experts in experimentally studying cognitive aging. The research contributions of this chapter are lessons learned from piloting successful and unsuccessful experimental procedures and analysis techniques. With my evaluation of the Cook's Collage as a replicable study, I contribute a "how-to" guide for creating appropriately motivated situations to induce cognitive failures and for analyzing physically observable interactions with a memory aid. I end this chapter by commenting how I leveraged experience from the long established field of memory research to apply onto the burgeoning new field of home technology research.

5.1 Challenge #1: Fishing for Phenomenon

The phenomenon of forgetting seems self-evident and commonplace since everyone can recall at least one real-life occurrence of failing to remember. However, how to find forgetting *in situ* is challenging. Martin advised, "one may distinguish three major methods of obtaining data on their occurrence. These can be referred to briefly as the observation, experimental simulation, and questionnaire methods. [Observation] is simple in principle. A collection is formed of as many as possible naturally occurring examples of the specified range of errors, a process that may be facilitated by the use of systematic aids to observation (including self-observation) such as special report forms or diaries. ...The advantage of corpora of cognitive failures is that they place taxonomic constraints on the nature of theories that might be proposed to account for such failures. ...In this method [of experimental simulation], cognitive failures are induced and studied experimentally. The best-known cognitive failure to be studied in this way is the tip-of-the-tongue phenomenon, in which a person is temporarily unable to retrieve a name or other word that subsequently returns to them. ...[Questionnaire] resembles the observation method in that it concerns itself with naturally occurring cognitive failures, but differs in that it is generic rather than specific. That is, it produces overall indices of individuals' susceptibilities to cognitive failure, rather than detailed descriptions of particular occasions on which this was manifested [73]."

I chose indirect simulation study for its high ecological validity from using cues or stimuli that have potential utility in the real-world and for its high generalizability from laboratory control and potential for programmatic replicability (as discussed in Chapter 2). While cognitive psychologists tend to conduct experimental studies of older adults (e.g., [15, 24, 25, 57]) as I have, interaction designers like myself tend to study technological support of human activity via deployment studies outside the laboratory (e.g., [52, 46, 51, 31]) as I may do in future work.

Still, I was able to induce and capture systematically the elusive yet ubiquitous phenomenon of forgetting by priming my indirect simulation study as the following details. That is, I specified the particular type of memory failure, constrained activity parameters, and targeted a particular user group.

5.1.1 Needle in Haystack

Forgetting results in incorrectly adding ingredients with respect to a given recipe; therefore, an ingredient error implies forgotten ingredient. This logic, a well known formal fallacy (i.e., converse error [1]), is invalid because *other* causes besides forgetting (e.g., incorrectly converting measurement units) can also result in incorrect ingredient additions. Clearly identifying the problem is key in studying the problem and not another problem. Clearly specifying the problem is challenging without establishing definitions and frameworks.

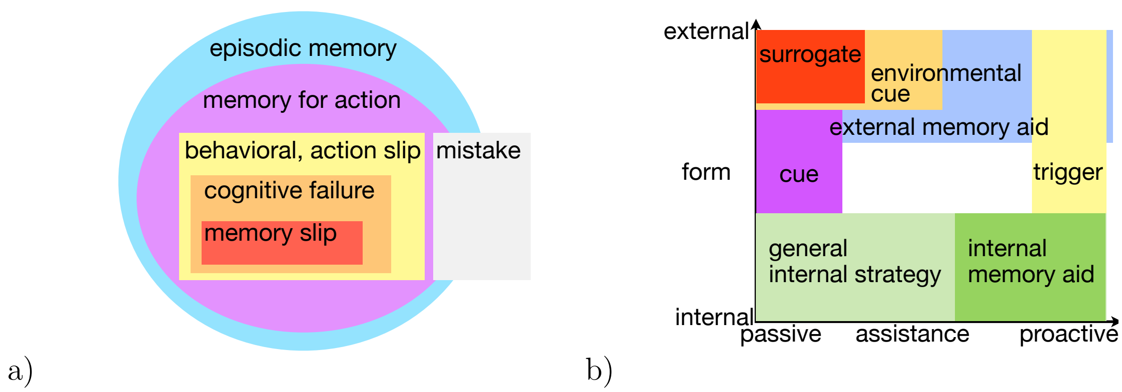


Figure 17: Conceptual space of memory a) types (in circles) and breakdowns (in rectangles) and of existing b) memory aids

Therefore, I sifted through the long history of memory research to form a conceptual model of memory *types* and *breakdowns* that pinpointed the specific type of memory breakdown I was studying. As Figure 17a shows, I discovered that *memory for action* was considered to be a specific type of episodic memory [117]. In differentiating breakdowns, I learned that "Errors come in several forms. Two fundamental categories are slips and mistakes. Slips result from automatic behavior, when subconscious actions that are intended to satisfy our goals get waylaid en route. Mistakes result from conscious deliberations [85]." Unraveling the mystery of slips, the cursory definition of forgetting exposed layers of breakdowns. I discovered I was studying memory slips [40] from the more general set of cognitive failures [74] from the more general set of behavioral or action slips [84].

With a better understanding of the memory problem, I sifted through the long history of memory aid research to form a design space of memory *support* and *form* as shown in Figure 17b. With the Cook's Collage as an example, I introduced a more specific set of support and form (i.e., deja vu displays) since labelled as memory surrogate by memory aid researchers.

5.1.2 Target User

Forgetting can happen to anyone. Although this may be true, the *frequency* and *probability* vary widely based on individual differences regarding memory ability, coping strategies, and memory aids. In testing the Cook's Collage at various prototyping stages, I recruited all age groups: youngest young (e.g., undergraduate students in psychology), younger young (e.g., graduate students in computing, working professionals in the local area), and senior adults. In evaluating memory augmentation, I targeted older adults.

Numerous memory studies have shown that memory *ability* decline with age; thereby, identifying older adults as a target user group with greater potential of *actually* benefiting from a memory aid. On the other hand, some memory studies have shown that *confidence* in everyday problem solving increases with age [16]; thereby, identifying older adults with lesser potential of *perceiving* benefit from additional assistance. Indeed, I was able to *induce* higher quantity of memory slips with older adult cooks which was critical in studying *behaviors* of memory ability. Additionally, the controlled laboratory setting was able to *capture* memory slips which was crucial in studying *attitudes* of memory confidence.

It is also important to note that I targeted habitual cooks after learning from my earlier studies that not screening out novice cooks allowed for ingredient errors not caused by memory slips.

5.1.3 Skilled Activity

Forgetting can happen during any activity. Although this may be true, the frequency and probability of forgetting vary based on activity characteristics. An arbitrary means to increase probability for memory slips is to increase difficulty of the assigned activities within the experiment which my earlier piloting yielded divergent breakdowns based on individual differences in cognition and not memory (e.g., measurement conversion, searching for ingredient on recipe). Thus, calibrating difficulty (i.e., not too easy but not too hard) for study participants in performing the activity is challenging but crucial for *inducing* memory *breakdowns*.

Surveying memory literature, I gained a better understanding of *why* human memory fails so that I could adjust activity parameters for my study participants with these problematic characteristics. For example, I chose ingredients (e.g., water, powder) that left minimal residual cues since display-based problem solving is robust [65]. For similarly reasons, I chose ingredients that required refrigeration until use to exacerbate the absence of memory triggers. With the activity parameters adjusted, I then devised distractions to the activity by replicating characteristics from previously effective interruption simulation studies (e.g., [36, 61, 63, 76]).

Also, calibrating appropriateness (i.e., not too artificial, not too non sequitur) of assigned activities for study participants is challenging but critical for *motivating* typical memory *habits*. I chose cooking as a familiar real-life activity that other simulation studies have demonstrated to motivate effort from older adults [24]. Within cooking, I chose adding ingredients as a *cohesive* sequence and *natural* flow of effortless *skill* because "Slips show up most frequently in skilled behavior. We don't make so many slips in things we are still learning. In part, slips result from a lack of attention. On the whole, people can consciously attend to only one primary thing at a time. But we often do many things at once. ...To play the piano, we must move the fingers properly over the keyboard while reading the music, manipulating the pedals, and listening to the resulting sounds. But to play the piano well, we should do these things automatically. Our conscious attention should be focused on the higher levels of the music, on style, and on phrasing. So it is with every skill. The low-level, physical movements should be controlled subconsciously [85]."

5.2 Challenge #2: Mining Internal and Automatic Process

In studying how people detect and recover from memory slips, I encountered three key method challenges. After initially unsuccessful piloting, I was able to make explicit the otherwise internal memory strategies and implicit coping mechanisms, minimize the observer effect [9] and Hawthorne effect [6] of my study participants, and encourage exploration of new memory habits from my study participants as follows.

5.2.1 Getting Physical

"Although slips are relatively easy to detect because there is a clear discrepancy between goal and result, detection can only take place if there is feedback. If the result of the action is not visible how can a mis-action be detected? Even when a mismatch is noted, the person may not believe that the error occurred. Some trail of the sequence of actions that was performed is valuable [85]."

Said differently, a record archive of events leading up to a memory slip and immediately following the memory slip is instrumental in disabusing the forgetful person from his/her perception of what happened by pairing objective observation with subjective self-reporting. Towards this end, I interviewed study participants about their activity performance in comparison with video transcripts of their activity performance to build external constructs of an otherwise internal process of detecting slips.

Also, I found video to be an effective medium for understanding *automatic* memory practices similar to Suchman's use of video for reflection and design [101]. What I gleaned from my video analyses echoed what Hollan, Hutchins, and Kirsh each concluded from their numerous cognitive ethnographies that "people form a tightly coupled system with their environments. The environment is one's partner or cognitive ally in the struggle to control activity. Although most of us are unaware of it, we constantly create external scaffolding to simplify our cognitive tasks [48]."

It is important to note that the *physicality* of memory for actions facilitates video observations. To enhance this natural feature, I physically distributed the locations of activity assignments for my study participants. In particular, I intentionally spaced apart within the kitchen the mixing bowl, required recipes, secondary activity, and the Cook's Collage display as to trace clearly the cook's eye gaze. For similar reasons, I devised interruptions physically removed from the kitchen. These strategic spacing only subtly influenced the behavioral process of maintaining cooking progress for the study participants while greatly facilitating the video analysis for me. In contrast, earlier attempts of employing cognitive walkthroughs [55] greatly changed the cooking process into a cooking show.

5.2.2 Getting Vocal

In my earlier studies, I realized young students exhibited the Hawthorne effect [6] by becoming silent in concentration of maintaining their activity progress to the point of almost ignoring distractions. To alleviate their test anxiety, I was advised to shift the focus from evaluating people's memory performance to evaluating their usage of the Cook's Collage. As a result, I chose to present my memory investigations for recruited participants as cooking management studies. In addition, I developed believable back stories to motivate more responsive attention for every distraction and to infuse familiarity of a real-life situation. I also separated the experimental proctor as an independent evaluator from the Cook's Collage technician. Moreover, the proctor encouraged participants to continue asking questions about the Cook's Collage throughout the study even as they cooked. I believed this open dialog and built rapport allowed for vocal outbursts from the cooks during experimental trials in reaction to the technical devices used in the study.

5.2.3 Getting Reflective

"People's perception of their memory are stable but not very accurate with respect to factors of kind of memory failures, susceptibility to cognitive failures under stress, confidence in memory performance, and age of subjects [45]."

Since a newly introduced memory aid is only as useful as it is used, I needed to somehow encourage participating cooks to try using the Cook's Collage as an exploration of new memory habits. In my earlier studies, I compared memory performances between individual cooks and between trial conditions only to discover that individual differences were too great from too small a sample set. I also realized that many cooks were too stable in their own coping strategies to try using a new device without continual arguments for change. As a result, I chose to repeat the same trial conditions time after time to increase the sampling size for comparisons within individual cooks and in hopes that the monotony induced boredom might prompt study participants to try something new. I separated cooking trials with at least one day to facilitate reflection, and I directly reported memory slips to expedite reconsiderations of memory habits.

5.3 Challenge #3: Measuring Augmentation

In defining success for the Cook's Collage as an example memory aid, I defined success for technological augmentation of any human activity by extension. In contrast to traditional measures of machine optimization for human productivity (i.e., Taylorism, automation), I sought new measures for extra automation of human engagement as follows.

5.3.1 Usage Choice

The Cook's Collage provides memory assistance if and when people choose to use it. For every opportunity of memory improvement, the cook remains in control and decides whether to accept or ignore the offered help. Therefore, I could not assume that the Cook's Collage automatically assisted at every opportunity because the cook was not required to comply. I needed to verify and qualify every actual use of the Cook's Collage. Albeit tedious video analysis, I was able to quantify percentages of use and non-use; thereby, establishing fundamental separation in evaluating augmentative technology.

5.3.2 Activity Enjoyment vs. Efficiency

The Cook's Collage focuses on the memory support of recently added ingredients so that the cook can focus on the human enjoyment of cooking. By choosing if and why to use the memory aid, the cook can maintain creative control in an open-ended recipe and thereby take pride in accomplishment. If the goal of the Cook's Collage as a memory aid were to eradicate ingredient errors at the cost of cooking engagement, it should be a cooking device that yielded the desired product automatically without shepherding the human through the perfunctory motions of the process. Thus, my analysis of the Cook's Collage focused on the qualitative illustrations from case studies of how cooks still enjoyed (e.g., by whistling, laughing) the process of cooking even with constant interruptions and distractions. My analysis did not include measurements of time resumption from interruptions as in evaluation studies of work-related memory aids [14] because cooking is not a rigidly structured activity.

5.4 Summary: Method Contribution

In this chapter, I motivated my method decisions in deriving the Repeated-Use Study (presented in the next chapter). I identified three main challenges in evaluating memory augmentation, and I discussed lessons learned in overcoming them. I described how I induced and captured memory slips with indirect simulation studies, how I studied internal memory strategies and implicit coping mechanisms, and how I qualified meaningful units of measurements to define success for the Cook's Collage.

As a student of human computer interaction and home technology, I was familiar with how to evaluate use of a technical device (e.g., the Cook's Collage). As a student of cognitive aging and psychology, I became familiar with how to evaluate memory ability, confidence, and use of a non-technical aid or coping strategy. Only together was I able to evaluate the Cook's Collage as a memory augmentation system.

CHAPTER VI

REPEATED-USE STUDY AND RESULTS

The purpose of this chapter is to present the Repeated-Use Study by describing its systematic procedures of experimentation, measurement, and analysis; and by reporting resulting user experiences reinforced with quantified percentages of emerging trends. The engineering contribution of this chapter is the evaluation protocol for the Cook's Collage as an example methodology in studying memory augmentation. The research contribution of this chapter is the resulting evaluation of the Cook's Collage regarding interaction design, technological limitation, and biases that provided insight into if, when, and how a novel memory surrogate did and did not support memory recall. To begin this chapter, I detail experimental procedures that simulated four distinct everyday cooking conditions within the kitchen laboratory, and I define analysis procedures and units of measurements that evaluated the resulting cooking sessions. To end this chapter, I report study findings that addressed my thesis questions. First, I report that memory slips *did* happen by comparing results of ingredient errors before the Cook's Collage was introduced, across the attention-demanding trial conditions, and across repeated use of the Cook's Collage over time; thereby, establishing my thesis premise and motivating the need for the Cook's Collage as *additional* memory cues. Then, I establish my fundamental conclusion that the Cook's Collage *can* assist memory recall of ingredients by *qualifying* representative user experiences of how the novel memory surrogate *interacted* with cooks within the busy kitchen. I temper this conclusion by recognizing how system and design limitations of the Cook's Collage hindered memory assistance in certain cases. Lastly, I report case studies that identified biases and barriers to using memory support.

6.1 Experimental Procedure

As Table 2 exemplifies, participants came to the Aware Home kitchen for five 90-minute sessions of four trial conditions over approximately two weeks. The sessions were spaced approximately two days between return visits in an effort to minimize practice effects while allowing for introspective reflection on performances and strategies. On the first visit (i.e., Session 0), the participants performed the trial conditions without the Cook's Collage; thereby, establishing individual baselines. Upon the second visit (i.e., Session 1), participants were introduced to the Cook's Collage with a video orientation, a recipe test-drive, and a hypothetical "tell-a-friend" promotion; and the Cook's Collage was subsequently made available for participants to use as desired (i.e. Sessions 1-4). Every session consisted of four trials with task assignments:

- P: punch recipe (i.e., cooking assignment)
- PS: punch recipe and stove (i.e., multitasking assignment)
- PSI: punch recipe, stove, and interruptions (i.e., alarms assignment)
- CSI: cookie recipe, stove, and interruptions

Table 2: Example sequence of trial conditions for one participating cook

Session 0	Session 1	Session 2	Session 3	Session 4
1. P	1. P	1. P	1. P	1. P
2. PS	2. PSI	2. PS	2. PSI	2. PS
3. PSI	3. PS	3. PSI	3. PS	3. PSI
4. CSI	4. CSI	4. CSI	4. CSI	4. CSI

Starting each session, participants first performed Trial P; thereby, refamiliarizing themselves with the cooking assignment. Trial CSI was always completed last; thereby, permitting participants to transfer their learned memory strategies to a somewhat unfamiliar recipe. Trials PS and PSI were counterbalanced between sessions. The task assignments are detailed as follows.

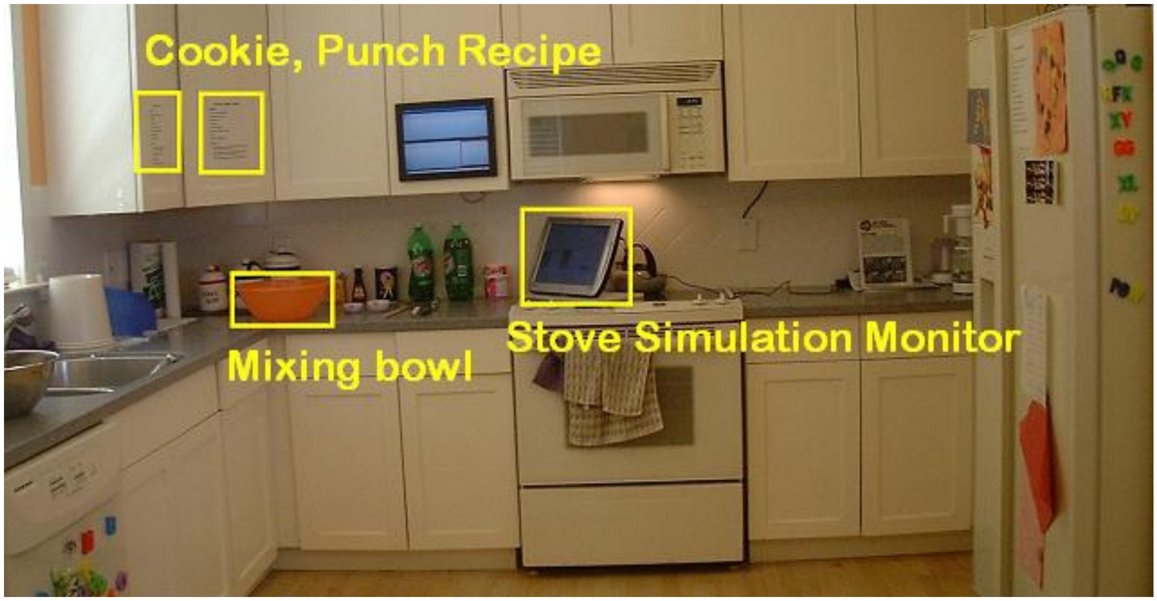


Figure 18: Kitchen locating posted punch and cookie recipes, stove simulation monitor, and mixing bowl with surrounding ingredients

6.1.1 Cooking Assignment

Table 3: Cooking Assignment

Punch Recipe			Cookie Recipe		
Ingredient	Count	Measurement	Ingredient	Count	Measurement
1. powder	4	$\frac{1}{4}$teaspoon	1. flour	5	$\frac{1}{4}$cup
2. sugar	2	$\frac{1}{2}$cup	2. baking soda	1	$\frac{1}{4}$teaspoon
3. water	13	$\frac{1}{2}$cup	3. salt	1	$\frac{1}{4}$teaspoon
4. orange	3	scoop	4. butter	1	stick
5. pineapple	3	scoop	5. (white) sugar	1	$\frac{1}{4}$cup
6. soda	2+2	$\frac{1}{4}$teaspoon	6. brown sugar	3	$\frac{1}{4}$cup
	or 5	$\frac{1}{3}$cup	7. egg	1	egg
7. sherbet	4	scoop	8. vanilla	4	$\frac{1}{4}$teaspoon

For the cooking assignment, I scripted two different recipes (i.e. punch and cookies) shown in Table 3 that required approximately the same number of steps and the same number of ingredients, and I provided a limited set of measuring utensils to require multiple additions for most of the ingredient measurements. As Figure 18 shows, I posted both recipes on the overhead cabinet panels where the cook could refer at them as needed. The eggs were stored in the refrigerator, and the frozen ingredients (i.e. both juice concentrates and sherbet) were stored in the freezer. All other ingredients were lined along the kitchen countertop. The proctor encouraged participants to rearrange items on the countertop as they wished; however, the proctor instructed participants to leave the bowl on its specifically marked spot, optimally positioned for the monitoring cameras. The proctor asked participants to add the ingredients in whichever sequence they wanted, but the proctor instructed the cooks to adhere with the measurements specified on the recipe. The proctor advised participants to cook at a comfortable pace since time was of no concern. I evaluated the cooking assignment in terms of ingredient accuracy as I will define later in this chapter.

6.1.2 Stove Monitoring Assignment

I added a stove monitoring assignment to the cooking assignment; thereby, creating a multitasking situation. I wanted to the divide visual attention of the cook so that I could investigate how people balanced their attention between tasks. The proctor informed participants that they were cooking dinner for friends and family members visiting their home. Three dishes (i.e., cheese sauce, chili, and tomato soup) simmering on three different stove burners shown in Figure 19 were represented by colored vertical bars that increased and decreased in height as the food heated up or cooled down; thereby, reflecting the cooking temperature of each dish. The stove monitoring assignment was to keep the temperature of each food in the neutral zone where it was neither burning nor cooling. Participants did this by toggling the HIGH/LOW switch. Pressing the HIGH button stopped the item from cooling and restarted to heat it, and pressing the LOW button stopped the item from heating and restarted to cool it. The three simulated burners randomly increased and decreased in height at different rates, and the neutral zones per item were of different lengths and positions. For example, the cheese sauce zipped outside the neutral zone in a matter of seconds whereas the tomato soup and chili took longer to creep outside the neutral zone. I evaluated the stove monitoring assignment in terms of time percentages the food items remained either burning or cooling.

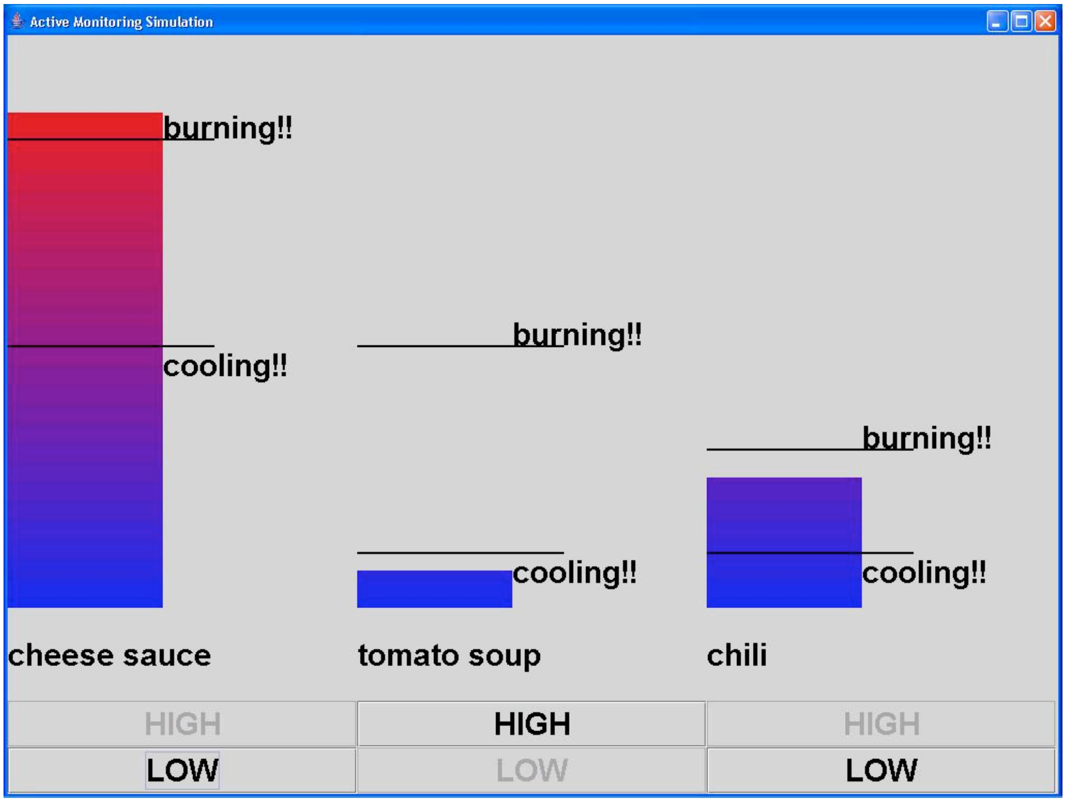
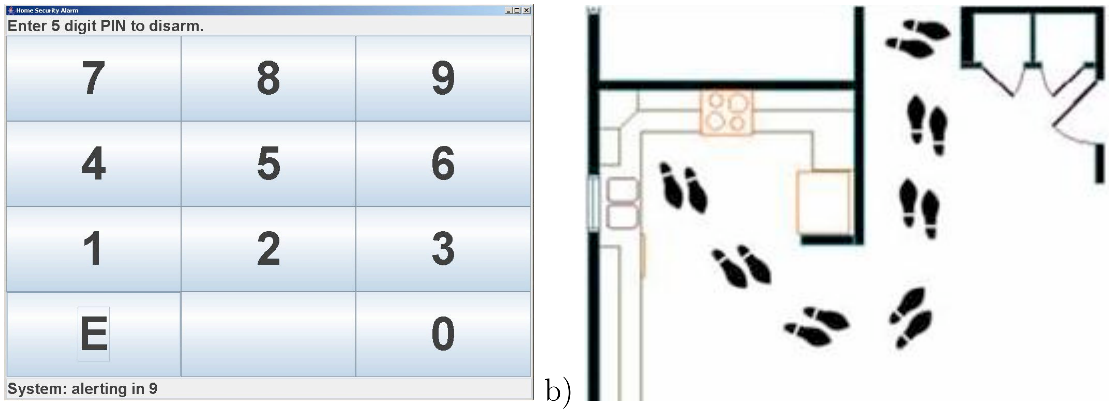


Figure 19: Stove simulation showing that cheese sauce is burning, tomato soup is too cold, and chili is simmering fine.

6.1.3 Alarm Interruption Assignment

I added an alarm system assignment to the stove monitoring assignment and cooking assignment; thereby creating an interruptive situation. I wanted to interrupt the two other tasks frequently to investigate how participants resumed their tasks after being distracted. The proctor informed participants to suppose that their friend were installing a new security system downstairs and that they were to help their friend by disabling the system when the alarm happened to be activated accidentally. At the start of each Trial PSI and CSI, the participants chose a 5-digit number that they thought they would remember if they should need to use it. Upon each



a) b)

Figure 20: a) Alarm key pad display with beeping sounds during the 25-second response time, b) located in the hallway around the corner from the kitchen.

sounding alarm interruption, participants disabled the beeping alarm by walking over to the alarm key pad (shown in Figure 20a) from around the corner of the kitchen (as shown in Figure 20b) and entering their chosen 5-digit number within the allotted 25-second response time. Otherwise, the alarm key pad would prompt for a new 5-digit number to be entered; thereby, requiring more time for the interruption away from the cooking assignment and stove monitoring assignment. Therefore, participants were encouraged to respond in a timely manner for every alarm. Alarm interruptions occurred randomly, with a minimum of one interruption every 90 seconds. Alarm interruptions can also occur back to back, with only about 10-15 seconds between alarms. I evaluated the alarm assignment in number of occurrences when the sounding alarm was not resolved within the allotted time.

6.1.4 Cook's Collage Orientation

Participants were told the system keeps track of

- the ingredients added to a recipe and
- the number of times each ingredient was added.

Participants watched a brief demo video and listened to detailed descriptions of the memory surrogate's display features, namely how the collage updated new images and number annotations as new ingredients or repetitions of an ingredient were added to a recipe. The demo video also highlighted the system limitations. Participants were advised of variable time delay for each display update, and were pointed to the tortoise-and-hare timeline, an additional feature at the bottom of the Cook's Collage, as a status indicator for the amount of time delay. The participants were advised to use the timeline in determining how long the time delay was at a given moment by observing how far the tortoise (representing the system) was positioned behind the hare (representing the cook). The participants were told the goal of the Cook's Collage for this study was to reflect their ingredients' sequence and counts accurately at all times; however, they were cautioned that the display may be inaccurate sometimes due to technical and physical constraints. To minimize these inaccuracies, participants were advised

- to pause momentarily while adding an ingredient over the mixing bowl because the system might miss these quick movements otherwise, and
- not to add extra scoops adjusting for partial amounts because the tracking system might mistake these additions for full amounts and because precise measurements were not required for this study.

While the orientation to the Cook's Collage gave no hints of particular strategies to leverage the system as a useful memory surrogate, the purpose was to inform participants of the system's features and limitations; thereby, allowing participants to decide if and how to use the Cook's Collage.

After the orientation, each participant was given an example display of how someone has made biscuits (as shown in Figure 1), a "starter kit" with the required ingredients and a $\frac{1}{4}$ teaspoon. They were instructed to replicate the sample ingredients' sequence and amounts; thereby, producing a similar summary on the Cook's Collage. Concluding the task, participants were asked how they might explain Cook's Collage to a friend who did not know of the novel memory surrogate. Participants were allowed to ask clarification questions about the tracking system and memory display before and after every cooking trial.

6.1.5 Assignment Review

At the beginning of each subsequent session (i.e., Session 1-4), each participant was given feedback about her/his assignment performances from the previous session (i.e., Session 0-3). The proctor carefully phrased the participant's assignment performances in an effort to praise positive performances and to encourage further improvement in overall performance. As an example, Table 4 and the following excerpt reprise the assignment review of Mr. A's Session 3.

Table 4: Assignment Review of Mr. A's Session 3

Trial	Ingredient Errors	Time % of Burning vs. Cooling		
P	*-2 powder*	Cheese Sauce	Chili	Tomato Soup
PS	*-2 powder*	1	4	47
PSI	*-2 powder* no sugar	15	24	49
CSI	-2 flour *-3 vanilla*	38	53	52

"Welcome back Mr. A. From your previous visit, you added the ingredients almost all correctly but for the punch recipe with the interruptions and the stove, you did not add the sugar at all; and for the cookie recipe with the interruptions and the stove, you added two less scoops of the flour. Also, let me remind you that the cookie recipe requires 1 teaspoon of vanilla which converts to 4 scoops of the $\frac{1}{4}$teaspoon provided; and that the punch recipe requires 1 teaspoon of powder which converts to 4 scoops of the $\frac{1}{4}$teaspoon provided. For the alarms task, you successfully turned off every alarm in time, so that is great. For the stove task, you did much better. When you had just the stove and the punch recipe, you left the cheese burning or cooling 1% of the time- that's really good, the chili 4%, and the tomato soup 47%. When you had the stove and the alarms and the punch recipe, you left the cheese burning or cooling 15% of the time, the chili 24%- that's good, and the tomato soup 49% of the time. When you had the cookie recipe and the stove and the alarms, you left the cheese burning or cooling 38% of the time, the chili 53%, and the tomato soup 52% of the time. Your goal today is to improve overall- add the correct counts of ingredients, reduce the stove burning and cooling times, and continue to turn off the alarms in time. Are you ready to start?"

6.1.5.1 Inter-Rater Reliability of Assignment Review

Performance reviews of the stove monitoring assignment and the alarm interruption assignment were rated straightforwardly based on automatically archived response times. However, performance reviews of the cooking assignment required inter-rater reliability (described in following example) to

1. confirm visually ingredient errors from three different viewpoints (from proctor sitting behind the cook, video camcorder placed beside the cook, and Cook's Collage cameras positioned in front of the cook), and to

2. interpret any anomalous patterns of ingredient errors *within context*.

Continuing with the example of Mr. A's assignment review for Session 3 within context to his other sessions with the Cook's Collage available (in Table 16), Mr. A consistently added two extra amounts of powder for the punch recipe throughout this day's trials (i.e., in Trial P, PS, and PSI) whereas he had added the correct amounts in his previous visit (i.e., Session 2) after being reminded of the correct measurement conversions because he had similarly added two extra amounts of powder for the punch recipe throughout his first visit (i.e., Session 1). The differing context between the two days raised the probability of Session 3's (and Session 1's) errors for the powder ingredient as measurement conversion *mistakes* rather than *memory slips*. Also in Session 3, Mr. A added three fewer amounts of vanilla for the cookie recipe.

Upon further review of Mr. A's situational context from not having an interruption and not interacting with the stove monitoring assignment before and after adding the vanilla ingredient, it is probable that it was a measurement conversion mistake rather than a memory slip. Throughout the data tables of ingredient errors in this document, I indicate such cooking mistakes in *italic* font within the otherwise catalog of memory slips.

6.2 Units of Measurement

For each cooking trial, a camcorder along the side countertop of the Aware Home kitchen recorded video and audio of the participant's activity, and the proctor directly observed the participant performing the assignments. Using a structured interview after every trial, the proctor asked each participant about her/his strategy for each assignment as applicable. Each cook rated her/his self-confidence on a Likert Scale (1=no, 2=perhaps, 3=maybe, 4=probably, 5=yes) in response to two specific tasks:

- "Do you think you forgot to add any ingredients?"
- "Do you think you missed a step?"

After every trial, each cook also commented on and rated her/his use of the Cook's Collage with a Likert Scale (1=never, 2=few times, 3=sometimes, 4=most of the time, 5=all the time). The two-week study concluded with an exit interview for each participant. Reflecting upon accumulated experiences with and without the Cook's Collage, the cooks were asked of their opinions about the overall system, if they would use the Cook's Collage in their own home, and what (if any) improvements could be made so that they would want to use the memory surrogate at home. The proctor assured participants that negative and positive feedback about the Cook's Collage were equally valuable to the study. Full procedures of the experimental protocol are included in Appendix A, and Chapter 4 detailed the archival architecture for the Cook's Collage (i.e., system performance).

6.3 *Units of Analysis*

For participating cooks, the assignment review (e.g., Mr. A's Table 4) was pivotal because it cautioned against incorrect measurement conversions and encouraged overall performance improvement in all three assignments. For my thesis investigation, the *cooking* assignment review particularly was revealing. In this section, I expand upon the units of *video* analysis that generated the cooking assignment review and thereby the Cook's Collage evaluation.

6.3.1 Ingredient Accuracy

I classified accuracy for each ingredient as one of four exclusive categories:

- added correctly (i.e., no error);
- forgotten entirely (i.e., miss);
- under-counted or over-counted by some number (i.e., miscount); or
- measured unintentionally or for different purpose (i.e., cooking *mistake*).

I defined ingredient error by comparing the number of counts the cook added that deviated from the number of counts required from the recipe instructions (i.e., to criterion). To follow Mr. A's cooking assignment review, I represented Mr. A's three counts of flour as "-2 flour" in Table 4 to denote that Mr. A under-counted the required five counts of flour by two counts (i.e., -2). Similarly, I recorded Mr. A's extra count of the water ingredient as "+1 water" (see Table 16). All tables cataloging ingredient errors from throughout this document employ this number notation.

6.3.2 Ingredient Engagement

For purposes of evaluating the Cook's Collage as memory surrogate, I needed to define for *which* ingredient the cook was *using* the Cook's Collage. By reviewing video of cooking sessions, I noticed that every ingredient in my chosen recipes required the cook to open some sort of container before adding the contents into the mixing bowl, that all participating cooks performed one ingredient addition at a time, and that many of the participating cooks closed the ingredient container before proceeding onto the next ingredient. Hence, I defined ingredient engagement by *presuming* that an ingredient was *engaged* from the moment the cook opened the ingredient's container to when s/he closed the ingredient's container; thereby, *physically* delimiting the time span in which the cook worked with each ingredient. Conversely, I defined an ingredient as *unengaged* while it was stored in the refrigerator/freezer or while it remained unopened on the kitchen countertop. Additionally, I assumed that *at most one* ingredient was engaged at any given time. For example, I defined the water as engaged while the sink faucet was turned on and left running even if the cook was preoccupied with other tasks and interruptions. As another example, I defined the sherbet as unengaged if the cook retrieved the sherbet box out from the freezer to place it on the countertop as a physical reminder to not forget the ingredient or to complete the ingredient lineup as a memory strategy. If the cook proceeded to open a different ingredient container while the sherbet box remained open, I presumed the new ingredient as engaged in lieu of the unengaged sherbet.

6.3.3 Cook's Collage Usage

Since I designed the Cook's Collage as an at-a-glance summary, I assumed an *eye glance* towards the visual display constituted gleaning of memory information; thereby, defining use. Moreover, I surmised that the Cook's Collage was used for whichever ingredient was *currently* engaged *only*. However, I presumed that the Cook's Collage was not used if the cook glanced at the display but did not compensate his/her miscounted ingredient additions with the discrepant information revealed on the Cook's Collage; thereby, disregarding the memory display. I confirmed these video observations with the cook's own comments about having ignored memory assistance.

6.3.4 Corpus of Memory Episodes

It is important to note that *every ingredient* presented a *possibility* for a memory slip and that every ingredient added with the Cook's Collage available (i.e., Sessions 1-4) presented an *opportunity* for the Cook's Collage to aid or not aid the cook's ingredient accuracy; thereby, offering *quantitative* percentages from emerging trends. As Table 3 listed, the punch recipe required seven different ingredients, and the cookie recipe required eight different ingredients. Therefore, each participating cook experienced 29 possibilities for an ingredient error before being introduced to the Cook's Collage and 116 opportunities in requesting memory assistance from the Cook's Collage for a total of 145 comparisons of cooking situations *within each* participant. *Between comparisons* of all study participants (e.g., six older adults) formed a grand total of 870 ingredients (of which 696 ingredients could have been aided by the available Cook's Collage in contrast to the 174 ingredients before its introduction) and provided the data corpus for this chapter (see Table 5).

Table 5: Assigned number of ingredients with and without the Cook's Collage

(Trial) Recipe	Session 0	Session 1-4	Total
(P) Punch	7	28	35
(PS) Punch	7	28	35
(PSI) Punch	7	28	35
(CSI) Cookie	8	32	40
Total (per cook)	29	116	145
Total (of 6 cooks)	174	696	870

It is also important to note that the *situational context* (i.e., physical surroundings of any and all concurrent activities, participant's perception of their user experience) before, during, and after each possibility of a memory slip differentiates the current instance from another incident; thereby, befitting *qualitative* case studies between what I termed *memory episodes*. From my defined units of analysis, I classified memory episodes into the following six categorial combinations (in Table 6) to correlate ingredient accuracy with Cook's Collage usage in conjecturing about aided memory:

- A: Cook added ingredient *correctly* and *used* the Cook's Collage; thereby, implying aided memory.
- B: Cook added ingredient *correctly* but did *not use* the Cook's Collage; thereby, implying no memory need.
- C: Cook *miscounted* ingredient and *used* the Cook's Collage used; thereby, implying system limitations unaided or hindered memory.
- D1: Cook *miscounted* ingredient and did *not use* the Cook's Collage; thereby, implying some barrier to use and/or bias.
- D2: Cook *missed* ingredient so by *default* did *not use* the Cook's Collage; thereby, implying some barrier to use and/or bias.
- E: Cook *miscounted* ingredient because of a cooking *mistake* (e.g., incorrect measurement conversion) rather than because of a memory *slip*.

Table 6: Matrix pairings of memory surrogate usage with ingredient error

	No memory slip (correct add)	Memory slip (miscount + miss)
Cook's Collage not used	B	D1 + D2
Cook's Collage used	A	C
		Cooking mistake: E

6.3.5 Interpretation Limitation

It is important to note that the interview method cannot distinguish between study participants who did not want to *admit* their use of the Cook's Collage and their memory slips from those who were not able to recall their memory slips. The social stigma of aging memory may be more endemic for older adults than younger adults; thereby, identifying an extenuating limitation of subjective self-reporting.

Although physically *observing* actions provided viable units of analysis in correlating Cook's Collage usage with engaged ingredients, *interpreting* behavioral intent proved challenging (as discussed in the ensuing chapter); therefore, I conceded some limitations in evaluating Cook's Collage for memory surrogate. Most notably, I had to default missed ingredients as non-use cases for the Cook's Collage because the cooks *never* engaged in these ingredients to prompt for memory query. Missed ingredients also could have produced false use cases when a cook reviewed the Cook's Collage after completing the recipe in hopes of realizing the missing ingredient. Under my correlation definitions, I had to classify this memory situation as a false-positive use case for the last engaged ingredient and as a false-negative for the missed ingredient. In addition, ingredient errors were subject to interpretation as memory slips or as measurement conversion mistake although the interpretation sessions provided some inter-rater reliability in differtianting these ingredient errors. Lastly, defining *every* eye-glance as a Cook's Collage use may have produced false-positive use cases (i.e., when the cook did not need memory support) from involuntary eye glances or from random curiosity rather than for intentional query or confirmation of needed memory information. For these uncertain cases, I remained consistent in my quantitative classifications, and I offered qualitative discussions into these particular memory episodes as case studies throughout the resulting report as follows.

6.4 Older Adult Participants

Six older adults (3 men, 3 women) from the ages of 66-79 living locally within the city participated in this study. They were recruited from a personnel database of participants for age-related studies established by the School of Psychology at Georgia Institute of Technology. Throughout this document, I refer to the six participants (by name and gender) as Mr. F, Mrs. F, Mr. S, Ms. S, Mr. A, and Ms. J.

Table 7: Catalog of Mrs. F's Cooking Mistakes with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS					0
PSI					0
CSI		*+1 salt*	*-3 vanilla*	*+5 baking soda*	3
Count	0	1	1	1	

Tables 7-9 show that (Mrs. F, Mr. A, Ms. S) three of the six participants committed cooking mistakes throughout Sessions 1-4. It is important to note that no cooking mistakes were identified for Session 0; thereby, classifying all ingredient errors in Session 0 as memory slips. That is, all participants did understand their cooking procedures but did not maintain accurate status of their cooking process.

Table 8: Catalog of Mr. A's Cooking Mistakes with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P	*-2 powder*		*-2 powder*		2
PS	*-2 powder*		*-2 powder*		2
PSI	*-2 powder*		*-2 powder*		2
CSI	*-3 vanilla*		*-3 vanilla*	*-3 vanilla*	3
Count	4	0	4	1	

Table 9: Catalog of Ms. S's Cooking Mistakes with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS					0
PSI				*+1 pineapple* *+1 orange*	2
CSI			*-3 vanilla*	*-3 vanilla*	2
Count	0	0	1	3	

6.5 Result #1: Additional Memory Support was Needed

From the corpus of memory episodes introduced in the previous section, I report in this section whether additional memory support was needed during the various cooking conditions. That is, did the older adult participants forget or miscount ingredients? If so, how frequently did these memory slips occur and under which conditions? Results regarding these study questions demonstrated the need or lack thereof for additional memory support; thereby, establishing the *premise* upon which I could then investigate my thesis questions.

6.5.1 Higher Attention Demands Prone to More Memory Slips

With my four trial different conditions, I was able to establish that memory slips occurred more frequently (i.e., number of errors) and more problematically (i.e., type of error) when more attention was demanded. Table 10 tallies the number of memory failures without the Cook's Collage in Session 0.

Table 10: Number of Memory Slips Without Cook's Collage in Session 0

Trial	Mr. S	Mr. F	Ms. J	Mr. A	Mrs. F	Ms. S	Total	%
P	0	0	0	0	1	0	1	2%
PS	0	0	1	3	1	2	7	16%
PSI	1	0	0	1	2	4	8	19%
CSI	0	3	2	1	2	1	9	19%
Total	1	3	3	5	6	7	25	
%	3%	10%	10%	17%	21%	24%	14%	

Table 11: Catalog of Memory Slips Without Cook's Collage in Session 0

Trial	Mr. S	Mr. F	Ms. J	Mr. A	Mrs. F	Ms. S
P					+1 sherbet	
PS			-1 soda	no soda -1 orange -1 sugar	-1 water	-1 water -1 soda
PSI	+1 orange			no soda	-2 powder -2 water	no soda -2 water -2 pineapple +1 sherbet
CSI		-1 flour +1 b.sugar -2 vanilla	-1 sugar -2 b.sugar	no egg	+1 sugar -1 b.sugar	+2 flour

The noticeable increase from the one ingredient error from Trial P to the seven ingredient errors in Trials PS suggested the stove monitoring task (i.e., multitasking assignment) that divided the cook's attention from the cooking assignment created more breakdowns in memory recall. The eight ingredient errors from Trial PSI and nine ingredient errors from Trial CSI suggested that the alarm interruptions that distracted the cook's attention from the cooking assignment caused similar breakdowns in memory recall. The similar ingredient error types and counts in Trials PSI and CSI suggested that the different recipes were of similar task difficulty. I leveraged the known direct correlation between attention demand and cognitive failure [73] to show that multitasking and interruptions were key situational context consistently prone to memory slips; thereby, establishing the premise that memory slips do not occur randomly, sporadically, or infrequently.

6.5.2 Miscounted Ingredients

Under the various cooking conditions, I was able to observe that people did miscount ingredients. Table 11 catalogs memory slips without the Cook's Collage in Session 0. Hence, the ingredient errors in Session 0 established memory performance baselines that all six older adult participants did miscount at least one ingredient; thereby, justifying that additional memory support would be of benefit to them, particularly Mr. A, Mrs. F, and Ms. S who miscounted more often than most. Mr. S miscounted only one ingredient, exhibiting minimal need for additional memory support. Even after the initial cooking session, ingredient errors catalogued in Tables 12-17 show that all participants continued to miscount ingredient due to differing memory episodes; thereby, motivating sustainable need for additional memory support.

Table 12: Catalog of Mr. S's Memory Slips with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS	+1 water +1 soda		+1 water		3
PSI	-2 powder +1 water	+1 water		-1 pineapple +2 water	5
CSI					0
Count	4	1	1	2	

Table 13: Catalog of Mr. F's Memory Slips with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS	+1 pineapple				1
PSI	+1 water				1
CSI				-2 vanilla	1
Count	2	0	0	1	

6.5.3 Forgotten Ingredients

In addition to *quantifying* ingredient errors, I defined ingredient errors *qualitatively* by error type (e.g., miscounting and forgetting) to emphasize their dissimilar consequences. Miscounting ingredients produced minor alteration in food quality, but forgetting ingredients entirely can yield major consequences in food quality. The memory slips catalogued in Tables 12-17 show that (Mr. A, Ms. J, Ms. S, Mrs. F) four of the six participants did forget ingredients entirely.

Table 14: Catalog of Ms. J's Memory Slips with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS	no soda	no orange no pineapple	+1 orange -1 pineapple		5
PSI	no sugar				1
CSI					0
Count	2	2	2	0	

Table 15: Catalog of Mrs. F's Memory Slips with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS					0
PSI	+1 soda			-3 powder	2
CSI	no vanilla				1
Count	2	0	0	1	

Table 16: Catalog of Mr. A's Memory Slips with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P					0
PS	+3 water	+1 water		no soda	3
PSI	-1 water		no sugar	+1 water -1 sherbet	4
CSI	-2 flour no egg		-2 flour	-2 flour	4
Count	4	1	2	4	

Table 17: Catalog of Ms. S's Memory Slips with Cook's Collage Available

Trial	Session 1	Session 2	Session 3	Session 4	Count
P		no sherbet	no soda		2
PS	+1 water		no soda -1 sherbet	-1 pineapple	4
PSI	+2 powder -2 water	no sherbet -1 powder +1 orange	no soda	+2 water	7
CSI				-2 b. sugar	1
Count	3	4	4	3	

6.5.4 Repeating Memory Slips

It is important to note that over time (see Table 18), miscounting and forgetting ingredients still occurred; thereby, reinforcing my definition of ingredient errors as *cognitive failures* of ordinarily doable tasks. Each of the six participants completed the punch and cookie recipes correctly (shown as absence of ingredient error) at least once throughout their cooking assignments as cataloged in Tables 12-17 and Tables 7-9. Therefore, all the cooks understood the recipe instructions, and all the older adults were physically and cognitively capable of completing the recipes correctly. Hence,

Table 18: Number of Memory Slips with Cook's Collage available (Sessions 1-4)

Trial	Session 1	Session 2	Session 3	Session 4	Total	%
P	0	1	1	0	2	1%
PS	6	3	5	2	16	10%
PSI	8	4	2	9	23	14%
CSI	3	0	1	2	6	4%
Total	17	8	9	13	47	
%	10%	5%	5%	7%		7%

the ingredient errors did not result from the physical difficulty of general cooking but from the cognitive difficulty of various memory episodes.

It is also important to note that over time, people still committed ingredient errors when they did not use the Cook's Collage for additional memory support; thereby, suggesting that ingredient errors were not resolved with learning effects. Many participants commented that they had memorized the punch recipe and knew the ingredients "by heart" by the latter sessions when asked about their strategy for each cooking assignment; however, these same participants still committed ingredient errors. Also, *learned* coping strategies (if any) beyond using the Cook's Collage did not prevent cognitive failures from occurring. That is, *knowing* what to do (i.e., learning effect) still allowed for *forgetting* what to do (i.e., memory slip).

While the ingredient errors on the initial cooking day established baseline memory recall for the six older adults, the Repeated-Use Study focused on the *everyday* aspect of cooking at home because the *monotony* and *automaticity* of daily *routine* can challenge monitoring diligence necessary in *maintaining* high-functioning memory for actions. Table 19 reported 22 total instances (i.e., Categories D1 = 8, D2 = 14) throughout the two-week study in which the cook had miscounted and missed an ingredient respectively because s/he chose not to use the Cook's Collage as additional memory support. These non-use cases evidenced that people can commit memory slips when they revert back to past memory habits; thereby, exposing the *sustainable* need for and benefit of additional memory support. Conversely, Table

19 reported that the cooks added 45% of the ingredients correctly without using the Cook's Collage; thereby, disclaiming the need for additional memory support for *every* ingredient action. With balanced ingredient accuracy percentages, I believe these memory episodes were *representative* for everyday home cooking.

Table 19: Percentage of non/use-cases with the Cook's Collage available

	No memory slip (correct add)	Memory slip (miscount + miss)
Cook's Collage not used	315(45%)	8(1%) + 14(2%)
Cook's Collage used	320(46%)	23(3%)
		Cooking mistake: 16(2%)

6.6 Result #2: Cook's Collage did Benefit Memory Recall

From the corpus of 696 ingredients with the Cook's Collage available, 320 (46%) ingredients (from Table 19) were added *correctly* by cooks who *used* the Cook's Collage under these particular memory episodes (i.e., Category A in Table 6) that presumably benefitted their memory recall. I caution this number as an upper estimate of probable beneficial use since my definition of using the Cook's Collage by an observable eye glance toward the memory display may not necessarily constitute a visual review or intentional inquery of the ingredient currently being added (i.e., false positive). Therefore, I selected the following memory episodes to illustrate clearly *how* the Cook's Collage effectively supported memory recall. In describing user experiences and their emerging strategies in using the Cook's Collage, I provide insight into the first half of the second thesis question: Once people do interact with a memory surrogate, which design and implementation features provide *effective* memory support?

6.6.1 Initial User Impression

Although not a design nor implementation feature, the orientation and tutorial task for the Cook's Collage successfully preluded to each cook the memory benefits of using the visual summary as expressed by their initial statements. Ms. S commented, “[It] would be very handy if you were distracted. When you come back, it can tell you how many you put in there. It would just be a good idea, especially if you have young children and get disturbed a lot. It looks really good!” Mrs. F said, “This is good for keeping track of what you’re doing so you don’t have to. It can count the ingredients for you.” Ms. J said, “It can be used to keep track of what you’ve done and how many times you’ve done it.” Mr. A commented, “This is a cooking director for dummies! It’s a good double-check. You can look at it and say ’Oh, I need to add the egg [as my case].” Mr. F said, “It would be good if [I] were distracted while making a recipe.” Mr. S said, “It would help someone keep up with the counts.”

6.6.2 Sufficiently Contextualized Cue

What memory cues to provide pointed to a key *design* feature for the user experience. This section points to an *absence* of use cases that informed my thesis claim: *Visually summarizing activities by capturing items used within the activity in the same physical surroundings can provide sufficient context in recalling memory for actions.* From the data corpus of six older adults as participating cooks who used the Cook’s Collage for a grand total of 345 (50%) times out of a possible 696 opportunities, not one question nor comment about the information on the Cook’s Collage display was commented during interviews nor during the cooking trials.

This lack of confusion from the participating cooks sharply contrasted to the inevitable concerns and criticism from non-users (i.e., individuals who have not experienced cooking with the Cook’s Collage or who have not stood in the same physical position of the participating cooks in the Aware Home kitchen to orient their visual perspective of the ingredients shown in the Cook’s Collage in the first-person point of view). It is important to note that the Cook’s Collage orientation and tutorial assignment was instrumental for participants to connect visually with the countertop ingredients they added to the photographs of the same countertop ingredients on the Cook's Collage. For example, Mrs. F commented after performing her tutorial assignment that she should move inactive ingredients aside from the mixing bowl so she could see what she was adding from the Cook's Collage photographs. Comparing the confusion and lack of confusion between these two groups, I concluded their key difference of grounded context (from the Cook's Collage orientation and tutorial assignment) was sufficient and required for the Cook's Collage as a memory cue.

6.6.3 Complementary User Interaction

When to provide memory cues pointed to a key *implementation* feature for the user experience. This section reports use cases of the Cook's Collage that informed my thesis claim: *User interactions* with accurate memory cues that *complements rather than interferes* with user *attention, memory habits, activity constraints, and environmental surroundings* can effectively augment memory recall. The following case studies represent the range of complementary user interaction that resulted in memory augmentation. The first five use cases validated the ideal usage scenario (from Chapter 1) of how I envisioned a memory display could fit smoothly and naturally into people's cooking style. The next four use cases exhibited increasingly resourceful ways participating older adults adjusted their cooking habits to incorporate the Cook's Collage for memory support given its practical limitations. All nine examples illustrated how fluidly the Cook's Collage complemented user interaction to facilitate memory recall.

6.6.3.1 Resuming after interruption

Regarding Session 2's CSI trial, Mr. S explained, "I used it [Cook's Collage] to check the counts. The alarm came at the right times, giving it time to catch up with me." Further video review of this cooking episode confirmed how Mr. S added the flour ingredient correctly after an interruption by using the Cook's Collage in resuming his running count.

Mr. S started this cookie recipe by moving the flour container closer to the mixing bowl, opening the lid, and adding two scoops of flour. Upon his third scoop of flour, the alarm started beeping. Mr. S went ahead and added the third scoop into the mixing bowl, dropped the measuring cup into the flour container, and tapped a few stove buttons before scurrying to the alarm keypad. Upon return, Mr. S again tapped a stove button. Then, he looked up at the Cook's Collage which displayed three counts of flour, so Mr. S returned to the flour container. He added another scoop, glanced up at the Cook's Collage, added another scoop, tapped a few more stove buttons, and pointed at the Cook's Collage as if to confirm his flour count as completed. Then, Mr. S spun around to continue with the recipe, but not before another alarm interrupted him. Given my video observation and his interview comments, I concluded that Mr. S benefited from the Cook's Collage in resuming after an interruption.

6.6.3.2 Confirming memory recall

Regarding Session 1's PSI trial, Mr. F self-rated his use of the Cook's Collage as *sometimes* (3) commenting, "I used it without looking at it. I have it to rely on. It's nice not to use it but to have it. It's like an airbag." For Session 2's PSI trial, Mr. F explained,"I feel more confident about myself this time. It is a confidence building process. I used it [Cook's Collage] as a check. About 6 counts into the water when it said 6, that really helped me a lot during the process." Further video review of this cooking episode confirmed how Mr. F added the correct amounts of water by using the Cook's Collage in confirming his running oral count.

Mr. F started this punch recipe by following the recipe straightforwardly while attending to the stove and alarm assignments. Returning from his first interruption, he playfully exclaimed "fire!" upon noticing the stove display. Intermittently, Mr. F spoke aloud what he needed to do or was doing at the time. For instance, he muttered "sugar" while retrieving the sugar container closer to the mixing bowl, and later he read aloud from the recipe "thirteen half-cups of water" before the beeping alarm interrupted him. Upon return, Mr. F tapped a few stove buttons and then started his count of water by exclaiming "one!" with a quick glance towards the Cook's Collage and the recipe. After six straight water additions, Mr. F looked up towards the Cook's Collage again, tapped some more buttons on the stove, and added three more counts of water before responding to another interruption. Mr. F resumed with two more counts of water after giving himself some time by tapping the stove buttons. Even though the next alarm started beeping, Mr. F carried on with the final two counts of water before responding to the interruption. He returned to read the next step in the recipe (i.e., stirring), stir the mixing bowl, and attend to the stove. Mr. F did not look up towards the Cook's Collage again until after having added the next two ingredients. Given my video observation and his interview comments, I concluded that Mr. F benefited from the Cook's Collage in confirming memory recall.

6.6.3.3 Offloading running count

Regarding Session 1's PS trial, Mrs. F. self-rated her use of the Cook's Collage as "all the time" (5) and commented,"I depended on it. If you give me a crutch, I'm gonna use it. I feel like I didn't have to think as much because that was there. It was fantastic! I love the memory aid. One time, I waited mixing until it caught up, then added one more." Since Mrs. F did not specify for which ingredients she used the Cook's Collage, further video review of this cooking episode confirmed how Mrs. F added the correct amounts of orange concentrate and sherbet by using the Cook's Collage in offloading her running counts.

Mrs. F started this punch recipe by taking the sherbet box out from the freezer. Then, she took out both juice concentrates from the refrigerator and removed their lids. She began adding the powder, but not before she pushed a stove button. Then, Mrs. F proceeded with the recipe to add sugar, water, pineapple concentrate, and orange concentrate while monitoring the stove display. Mrs. F kept glancing at the stove display while adding the pineapple concentrate. When her first scoop of orange concentrate would not drop into the mixing bowl even after repeatedly tapping the ice cream scooper onto the mixing bowl to dislodge it, Mrs. F turned her focus to poke a few stove buttons. Then, she grabbed the nearby $\frac{1}{4}$ teaspoon to scrape out the sticky orange concentrate from the ice cream scooper. After which, Mrs. F looked up at the Cook's Collage, scooped out another count of orange concentrate from the container, poked a stove button, and rechecked the Cook's Collage while tapping out the sticky ingredient into the mixing bowl. Again, Mrs. F reviewed the Cook's Collage while scratching her nose and giving the display time to update. Then, she tapped a stove button, sat down the ice cream scooper, and started mixing the bowl while poking a few more stove buttons. As Mrs. F stirred, she watched the stove display and the Cook's Collage. Then, she sat down her mixing spoon and added the final third scoop of orange concentrate. After which, Mrs. F resumed stirring while exchanging glances between the Cook's Collage and the stove display. Then, she turned to the recipe for the next ingredient (i.e., soda). After adding and stirring in the soda, Mrs. F glanced up at the Cook's Collage.

Then, Mrs. F proceeded to add the last ingredient (i.e., sherbet) while attending to the stove display. Similar to the sticky orange concentrate, Mrs. F had difficulty tapping out the sherbet into the mixing bowl, so she again found the $\frac{1}{4}$ teaspoon to scrape out the sticky ice cream. On the third scoop, Mrs. F had difficulty scraping the thick blob of sherbet with the thin $\frac{1}{4}$ teaspoon; thereby, requiring several attempts. Then, she turned her attention to the stove display while stirring the mixing bowl. After which, Mrs. F repeatedly glanced up at the Cook's Collage while continuing to stir and attend to the stove. Then, she returned to the sherbet box for the final scoop of ice cream. As she added the sherbet and afterwards as she further stirred the mixing bowl, Mrs. F watched the Cook's Collage. When she saw what she was looking for, Mrs. F nodded her head, smiled, and announced to the proctor that she had completed the recipe. Given my video observation and her interview comments, I concluded that Mrs. F benefited from the Cook's Collage in offloading her running counts for the orange concentrate and sherbet.

6.6.3.4 Counting measurements

In Session 0 (i.e., prior to the Cook's Collage), Mrs. F explained the frustration with her straightforward cooking strategy. "I was trying to get it all done at one time- each ingredient that is- I couldn't do it though. I have no idea about the water. I may have added $\frac{1}{2}$cup more or less. With the water, I did a whole cup (i.e., $\frac{1}{2}$cup twice) before I'd check the stove. If I had thought about it in terms of 13, it would have been better." For Session 1's (i.e., first day with the Cook's Collage) P trial (i.e., without interruptions or multitasking), Mrs. F raved, "I learned to count by whole numbers rather than by $\frac{1}{2}$cups. For water, I counted up to 13, and I did check on the screen to see if I did what I wanted." Further video review of this cooking episode confirmed how Mrs. F adjusted her counting method to use the number annotations on the Cook's Collage.

Mrs. F started this punch recipe as she usually did by taking out ingredients from the refrigerator and freezer. Mrs. F began by reading the recipe (underlining with her index finger) for the first ingredient (i.e., powder) which she added. She read the recipe again (by underling with her index finger) for the second ingredient (i.e., sugar), but grabbed the flour container instead. She glanced at the Cook's Collage to confirm her counts from the first ingredient, searched among the measuring cups reading for the correct $\frac{1}{2}$cup for the sugar ingredient, and realized her slip of retrieving the wrong ingredient container. Double-checking with the recipe again, Mrs. F gave herself a scoff and proceeded to add the sugar. She continued by checking as before the recipe and measuring cups to add the water without interruption. Upon completing, she looked up at the Cook's Collage and up at the recipe. She proceeded to stir the mixing bowl while checking back with the Cook's Collage and recipe once more before proceeding onward. Mrs. F was visibly mouthing the running count for water as she added them into the bowl, but the audio record cannot confirm her counting units. Given my video observation and her interview comments, I concluded that Mrs. F added the correct amount of water by slightly altering her counting measurements to benefit from the Cook's Collage as a memory surrogate.

6.6.3.5 Waiting on delay

Regarding Session 2's PS trial, Mr. F explained, "I needed it [Cook's Collage] for the ginger ale [soda], I waited for it to catch up. I was distracted and needed it to tell me 4 or 5. I felt so comfortable when it said I had one more to add. It was great having that there. I guess it can be used as needed use it when youre thinking 'Whoops, what was I doing?' I used it every step I'd say. I had discrepancies [disagreements with the Cook's Collage] previously, but this time I wanted to get in sync[hronization] with it. I knew this was going to be better, and that I could count on the aid if I needed to. I didn't feel bad waiting for it to catch up, because I knew it would aid the overall quality of the result." Further video review of this cooking episode confirmed how Mr. F added the correct amount of soda by waiting on the time delay.

For the soda ingredient, the Cook's Collage system recorded a five second delay. Mr. F added the first three counts of soda without interruption. Then, he turned his attention to the stove display, realizing aloud "Oops!" and tapping a few stove buttons. Returning to the soda bottle, Mr. F rechecked the stove display and glanced quickly at the Cook's Collage while pouring another count. After which, he rechecked the Cook's Collage, muttered "Come on!" in response, sat down the soda bottle to tap a few more stove buttons, glanced again at the Cook's Collage asking "One more? Argh." He repeated this waiting procedure until he could clarify his running count "Come on, catch up! Four? Five?" and once more before exclaiming "Green means you're [Cook's Collage] caught up. Ok!" Mr. F added the final count of soda, pushed the soda bottle back along the countertop, glanced at the stove display, and turned his attention to the Cook's Collage while stirring the mixing bowl. After one second reviewing the Cook's Collage, Mr. F proclaimed, "Good!" Then, he continued on with the recipe. Given my video observation, the Cook's Collage system records, and his interview comments, I concluded that Mr. F used the Cook's Collage by waiting on delays to receive memory benefit.

6.6.3.6 Readying final count

Regarding Session 4's P trial, Ms. J explained, "I counted all 12 water [counts], put the 13th [half] cup down, then put it in when I saw the tortoise next to the hare [on the Cook's Collage display]." Further video review of this cooking episode confirmed how Ms. J added the correct amounts of water by readying her final count to benefit from the Cook's Collage as a memory surrogate.

Ms. J started this punch recipe by wistfully asking, "What are we going to do today?" She began by adding the powder but not before stopping herself to double-check the measuring utensil in hand with the recipe. Then, Ms. J opened the sugar container, spilling out sugar and exclaiming "Uh oh!" She scoffed, raised her other hand in disbelief, raised her eyebrows, frowned, and carried on with adding the sugar. After a quick look at the Cook's Collage and recipe, Ms. J turned her attention to the sink. She calmly added twelve straight counts of water without interruption, filled up the thirteenth count of water, turned off the sink, and placed the water cup on the countertop beside the mixing bowl. Then, Ms. J glanced at the Cook's Collage and at the recipe, and started stirring the mixing bowl. After a few seconds, she rechecked the Cook's Collage and the recipe, slowly reached for the remaining water cup, triple-checked the Cook's Collage and recipe, and slowly added the final water count. Mixing a little further, Ms. J read the next step in the recipe and went to the refrigerator to retrieve the next ingredients (i.e., juice concentrates). Given my video observation and her interview comments, I concluded that Ms. J slightly deferred her final count of water so that she could confirm with the Cook's Collage; thereby, benefitting from its memory assistance.

6.6.3.7 Returning to ingredient

Similar to Mrs. F offloading her running counts and Mr. S resuming from his interruptions, Ms. S discovered a third added value in using the Cook's Collage. From Session 3's PSI trial, Ms. S explained, "I used it [Cook's Collage] for doing the water. I had it count for me because when I go to the bell, I had to come back and check it. I saw that I needed to add more." Further video review of this cooking episode confirmed how Ms. S used the Cook's Collage in returning to a previously added ingredient to complete the correct amount.

Ms. S started this punch recipe by taking the sherbet box out from the freezer. Then, she took out both juice concentrates from the refrigerator. The alarm started beeping, so Ms. S tapped a stove button as she went to the alarm key pad. She proceeded along the recipe list while responding to more intermittent alarms and toggling stove buttons. Ms. S added powder, sugar, water, orange concentrate, and pineapple concentrate. While she was adding the last count of pineapple concentrate by scraping the ice cream scooper with the wooden spoon, Ms. S reviewed the Cook's Collage which displayed nine counts of water. She proceeded to open the sherbet lid and attended to the stove, but she returned to the sink for three additional counts of water. Upon her third count of water, the alarm sounded again. Ms. S went ahead and added her water, turned off the sink, and attended to the interruption.

Upon return, she reviewed the Cook's Collage again while whistling. Then, Ms. S. turned to the sink for the final count of water and added it to the mixing bowl before continuing on with the recipe by reorienting the sherbet box, adjusting the stove gauges, and adding the sherbet. Given my video observation and her interview comments, I concluded that Ms. S added the correct amount of water by improvising her ingredient additions to benefit from the Cook's Collage as a memory surrogate.

6.7 Result #3: Cook's Collage was Limited in Assistance

From the possible 696 ingredients with the Cook's Collage available, only 23 (3%) ingredients (from Table 19) were added *incorrectly* by cooks who *used* the Cook's Collage under these particular memory episodes (i.e., Category C in Table 6) that presumably did *not* benefit their memory recall. Therefore, I selected the following use cases to illustrate clearly the limitations of the Cook's Collage as effective memory support. Chapter 4 classified 12 wizard of Oz errors in monitoring that directly caused an ingredient miscount; thereby, identifying an implementation limitation. The remaining 11 use cases I attribute to time delays in updating the Cook's Collage display as another key implementation limitation. However, I caution the remaining 11 use cases as an upper estimate of probable use since my definition of using the Cook's Collage by an observable eye glance toward the memory display may not necessarily constitute a visual review or query of the ingredient currently being added (i.e., false positive). In describing use cases with these limitations, I provide insight into the latter half of the second thesis question: Once people do interact with a memory surrogate, which design and implementation features *did not* provide effective memory support?

6.7.1 Monitoring Miscount

When asked if he thought he missed a step in Session 3's PS trial, Mr. S explained, "No. If the aid is right on the water then I'm fine." However, records of wizard of

Oz errors and further video review of this cooking episode revealed how the Cook's Collage incorrectly monitored his water counts; thereby, causing Mr. S to add one extra count of this ingredient.

Mr. S started the punch recipe by adding the powder without interruption. Then, he turned his attention to the stove display, added the sugar without interruption, poked a few more stove buttons, glanced at the Cook's Collage, read the recipe, and started adding water while tending to the stove display intermittently. Mr. S looked at the Cook's Collage after his sixth count of water, struggled with tapping the stove buttons, added one more water before reviewing the Cook's Collage, added three more counts of water, poked the stove display, and added another count of water. Then, he placed down his measuring cup, looked at the Cook's Collage, struggled with more stove buttons, rechecked the recipe, turned off the water, and stepped back waiting for the Cook's Collage to update. After a moment, Mr. S exclaimed, "Oh!" He returned to the sink and added three more counts of water.

From system monitoring records regarding this cooking episode, the wizard of Oz incorrectly recognized that Mr. S had added thirteen counts of water whereas the video record showed that Mr. S actually added fourteen counts of water. The monitoring records also showed that the wizard of Oz incorrectly recognized two other ingredients (i.e., powder and soda) for this cooking trial, but these recognition errors were inconsequential because the video review showed that Mr. S did not use (i.e., look at) the Cook's Collage for these particular ingredients. Given my video observation, his interview comments, and wizard of Oz records, I concluded that Mr. S miscounted water because of a monitoring miscount by the Cook's Collage.

6.7.2 Update Delay

Regarding Session 1's PS trial, Mr. F commented, "I wish it was a little faster. The time gap means limited use. I used it [Cook's Collage] for checks along the way, but when I went faster, I no longer had the validation of the count. I said I'm right and I'll see if it's [Cook's Collage] on the right number at the end." When asked if he missed a step, Mr. F self-rated his confidence as *perhaps* (2) explaining, "Maybe, because of the uncertainty of the [pineapple] concentrate measurement." Further video review of this cooking episode revealed how Mr. F added one extra count of pineapple concentrate because he did not use the Cook's Collage until *after* he had completed this incorrect addition.

Mr. F started this punch recipe thinking aloud while following the recipe and stove display: "Two teaspoons of the... drink mix. Ooh! Ok- where everybody's [stove]... good- huh. Oh, I've started daydreaming to set up a good screen. I want two teaspoons here. How are we doing guys [stove]? That's four of these [$\frac{1}{4}$ teaspoon]. One, two, three, four." Then, Mr. F proceeded with adding the sugar. After which, he reviewed the Cook's Collage and the recipe muttering measurement conversions and gesturing finger counts. Satisfied, Mr. F continued to add the water by muttering his running count while monitoring the stove display intermittently. While stirring the mixing bowl, Mr. F looked up at the Cook's Collage several times. After retrieving the juice concentrates and sherbet onto the kitchen counter, Mr. F read the next step muttering "Go to step two- orange juice and pineapple juice concentrates," opened the container lids, exclaimed his surprise at the stove display with a "Oh!" as he poked at some stove buttons, tapped into the mixing bowl two scoops of pineapple concentrate, and scraped in another count of pineapple concentrate before poking a few more stove buttons. Then, Mr. F glanced at the Cook's Collage which had yet to update, rechecked the recipe muttering, "Looks like two, and I need three scoops." He poked at the stove display twice more and scraped in an additional scoop of pineapple concentrate. Then, Mr. F proceeded adding three scoops of orange concentrate without interruption. Afterwards, he tended to the stove display again and turned his attention to review the Cook's Collage. Mr. F exclaimed, "Ouch!

It said I did four of those. Huh." Then, the stove display grabbed his attention, so Mr. F tended to it exclaiming, "Oh my goodness!" Mr. F returned his attention to the Cook's Collage commenting, "Really distracted trying to figure out what I did." System records from the wizard of Oz documented a four second update delay in displaying the pineapple concentrate ingredient. Given my video observation, his interview comments, and Cook's Collage performance records, I concluded that Mr. F added an extra count of the pineapple concentrate because he *chose* to not to wait for the slower update delays of the Cook's Collage; thereby, not benefiting from the Cook's Collage as a memory surrogate.

It is important to note that Mr. F could not have *undone* the extra addition of pineapple concentrate because the ingredient had already melted with the water in the mixing bowl; thereby, suggesting an inherent *design* limitation of having unavailable undo for *cooking* support.

It should be noted that the Cook's Collage did not alert Mr. F of his (imminent) over-counting as he was adding the additional scoop of pineapple concentrate; thereby, indicating an inherent *design* limitation of having a non-alerting aid for memory *recall*.

It is also important to note that Mr. F remained not fully convinced that he miscounted the pineapple concentrate. The Cook's Collage gave him pause (literally) during the cooking trial to recall his actions, but the memory device could only introduce doubt into Mr. F's confidence that he did not miscount. Thus, this use case pointed to another inherent *design* limitation of trusting memory surrogates.

6.8 Result #4: Biases did Deter Assistance

From the corpus of 696 possible ingredients with the Cook's Collage available, 22 (3%) ingredients (in Table 19) were either miscounted or missed entirely by cooks (listed in Table 20) who *did not use* the Cook's Collage for these particular memory episodes (i.e., Category D1 and D2 in Table 6). Assuming that the Cook's Collage *could have* corrected these ingredient errors if used notwithstanding design and implementation limitations, *why* did the cooks *choose* not to use the provided memory cues? In the following sections, I present illustrative non-use cases and self-reported commentary that provided insight into my first thesis question: When provided with a novel memory surrogate, what *biases* deter people from using available memory cues?

Table 20: Number of Non-Use Cases with Memory Slips

Memory Slip Category	Mr. S	Mr. F	Ms. J	Mr. A	Mrs. F	Ms. S	Total
Miscounted (D1)	1	0	0	5	0	2	8
Missed (D2)	0	0	4	3	1	6	14

6.8.1 Skewed Self-Confidence

By asking every cook after each cooking trial for a self-confidence rating regarding ingredient accuracy, I discovered a key discrepancy that can suggest user bias. Table 21 lists the names of participants who doubted their ingredient addition(s) and shows the remaining number of participants who confidently answered, "No. I definitely did not forget any ingredient." All but one participant (i.e., Ms. J conceded *maybe* for Session's 3 CSI trial and *perhaps* for Session 4's CSI trial) self-reported the highest confidence rating. Similarly, Table 22 names the participants who doubted their ingredient count(s) and shows the remaining number of participants who confidently answered, "No. I definitely did not miss a step." The sparsity in both Tables 21 & 22 suggest a high self-confidence in memory ability notwithstanding the inherent limitations of self-reporting (to be discussed in Chapter 5). However, the participants' high memory *perception* sharply contrasted with their *actual* lower memory performances (see Tables 10-18). This empirical disparity reinforced a well-known memory introspection paradox stating that participants who are most likely to *make* memory errors are also the same ones most likely to *forget* that such an error took place [43].

Table 21: Participants' Likert Responses to Possibly Missing Ingredients

Session	Trial	*No*	*Perhaps*	*Maybe*	*Probably*	*Yes*
0	P	6				
	PS	6				
	PSI	6				
	CSI	6				
1	P	6				
	PS	6				
	PSI	6				
	CSI	6				
2	P	6				
	PS	6				
	PSI	6				
	CSI	6				
3	P	6				
	PS	6				
	PSI	6				
	CSI	5		Ms. J		
4	P	6				
	PS	6				
	PSI	5	Ms. J			
	CSI	6				

From my Repeated-Use Study, participants with the most memory slips during non-use cases (i.e., Mr. A, Ms. S listed in Table 20) were the same ones who least doubted their ingredient additions and who expressed *surprise* when their assignment reviews apprised missed and miscounted ingredients; thereby suggesting their *unawareness of memory need*. To illustrate clearly this disconnect between perceived and actual memory ability, I report a representative non-use case as follows.

6.8.1.1 *Discounted Memory Correction*

When asked if he thought he had missed a step in Session 4's PSI trial, Mr. A replied, "*No.* [I definitely did not] (1)." He added sarcastically,"But the memory aid says I did an extra water. It says it, so it must be true." Further video review of this cooking episode confirmed how Mr. A *disregarded* the Cook's Collage when it displayed him over-counting the water ingredient; thereby, *choosing* not to use the

Table 22: Participants' Likert Response to Possibly Miscounting Ingredients

Session	Trial	*No*	*Perhaps*	*Maybe*	*Probably*	*Yes*
0	P	5		Ms. J		
	PS	5		Mr. F		
	PSI	3		Mr. S Mrs. F		Mr. F
	CSI	5		Mrs. F		
1	P	6				
	PS	5	Mr. F			
	PSI	5		Ms. S		
	CSI	5		Ms. J		
2	P	5			Mr. F	
	PS	6				
	PSI	5			Mr. F	
	CSI	5		Mrs. F		
3	P	6				
	PS	6				
	PSI	6				
	CSI	6				
4	P	6				
	PS	5				Mr. S
	PSI	4				Mr. S Mrs. F
	CSI	5	Mr. F			

memory surrogate when it conflicted with his own memory belief.

Mr. A started this punch recipe by responding to an alarm (whistling) and commenting, "Boy, it went off before I even got started!" He returned to address the stove display muttering, "Oh- don't do that." Then, Mr. A proceeded with the recipe by adding the powder, sugar, and water while tending to the stove display and alarm interruptions intermittently. After his fifth count of water, the alarms interrupted again. Upon returning to the kitchen, Mr. A poked at the stove display while humming, pointed at the Cook's Collage, and added another count of water before responding to another alarm. Upon this return, Mr. A looked at the Cook's Collage again and added five more counts of water before tending to the stove display. Then, he glanced at the Cook's Collage and added three additional counts of water (totaling fourteen) before tending to another alarm. Upon return, Mr. A tended to the stove display, pointed at the Cook's Collage which displayed fourteen counts of water, and exclaimed, "Dang. Well, that's [Cook's Collage] wrong! Hahaha." Then, Mr. A read the recipe to continue on with the next ingredients (i.e., juice concentrates) which he retrieved from the refrigerator before attending to another alarm. Given my video observation and his interview comments, I concluded that Mr. A chose to discard the information reported by the Cook's Collage in deference to his own memory recall; thereby, pointing to a user bias of skewed self-confidence in discounting memory correction as a variant phenomenon on the memory introspection paradox.

6.8.2 Predilection to Own Memory Routine

This section reports representative non-use cases of the Cook's Collage that informed the latter half of the thesis claim: *Barriers to using provided memory cues can include* unawareness of memory need and *predilection to own memory* ability and *routine*. The previous section informed the first half of this thesis claim.

6.8.2.1 Focused change in routine

When asked how much she used the Cook's Collage, Ms. S self-rated *never* (1) for Session 2's P trial, but Ms. S remarked for Session 2's PSI trial that she "used it a lot when adding the *water* and when going to the alarm to see if [I had] the correct *measurements*." However, It is important to note that Ms. S did not comment about using the Cook's Collage for *ingredients*; thereby, indicating her *focused* use of the memory surrogate.

Video review of Session 2's P and PSI trials confirmed that Ms. S failed to add the sherbet ingredient into the mixing bowl even though she had retrieved it from the freezer and placed it directly beside the mixing bowl supposedly as a visual reminder to add it as the last ingredient listed on the punch recipe. For Trial P, Ms. S followed the punch recipe to add the listed ingredients in a straightforward sequence at a relaxed pace without any distractions and without once looking up at the Cook's Collage. She added the powder, sugar, and water. Then, Ms. S went to the refrigerator to retrieve both juice concentrates and to place them beside the mixing bowl. She returned to the freezer to retrieve the sherbet. With the sherbet box placed beside the mixing bowl, Ms. S proceeded to add the pineapple and orange concentrates. Then, she opened the soda bottle, read the recipe, and poured in the correct amounts. As soon as she finished with her soda counts, Ms. S declared that she completed the recipe even with the unopened sherbet box directly in front of her. For Trial PSI, Ms. S started by attending to the stove display and then sounding alarm before following the punch recipe in a straightforward sequence similar to Trial P to add the powder, sugar, and water while tending to the stove display and alarms intermittently. Then, Ms. S retrieved both juice concentrates and the sherbet box in the same manner as in Trial P, and she proceeded in her same routine to add all ingredients while tending to the additional distractions. Ms. S declared that she completed the recipe as soon as she added the final count of soda even with the unopened sherbet box again directly in front of her. Unlike Trial P, Ms. S did look up at the Cook's Collage during this cooking episode for all ingredients but the second (i.e., sugar) and required last (i.e., sherbet) ingredients, and she did refer to the recipe for every ingredient she did add. For these cooking episodes, her routine of retrieving the sherbet at the point in her recipe sequence that required retrieving the juice concentrates was not sufficient in reminding her to add the sherbet.

Upon learning her forgotten sherbet ingredient, Ms. S changed her recipe routine to focus on her problematic ingredient. She explained, "This time [Session 3], I put the frozen ingredients out first, so I wouldn't forget the sherbet." For Session 3's P trial, Ms. S reported her use of the Cook's Collage as *sometimes* (3) commenting, "I used it when I was doing the water and at the *end* to check my *measurements*." For Session 3's PS trial, Ms. S commented, "I used it a lot, about half of the time for the water and for the count on the *sherbet*." Again, it is important to note that Ms. S did not comment about using the Cook's Collage for *ingredients*; thereby, indicating her *focused* use of the memory surrogate.

Video review of Session 3's (P, PS, PSI) trials with the punch recipe confirmed that Ms. S subsequently failed to add the soda ingredient that was directly beside the mixing bowl for all punch recipe trials. In fact, *two* soda bottles remained along the countertop wall (amongst the powder, sugar, and flour ingredients) throughout Session 3 for Ms. S to use, but she did not once reach for either soda bottle. Ms. S started all three punch recipes during Session 3 by retrieving (the juice concentrates and) the sherbet box from the freezer to set beside the mixing bowl. Otherwise, she followed the sequence as listed on the recipe similar to her previous sessions. In Trial P, Ms. S added powder, sugar, water, orange concentrate, and pineapple concentrate without interruption. Without pausing, Ms. S opened the sherbet box, proceeded to add all counts of the sherbet, and reviewed the Cook's Collage muttering, "ok, let's see." Satisfied, Ms. S announced to the proctor that she was done without once having touched either soda bottles for this recipe. For Trial PS, Ms. S followed the recipe in a similar fashion while tending to the stove display. She added powder, sugar, and eleven counts of water. She placed an additional count of water beside the mixing bowl and proceeded to add the pineapple concentrate, orange concentrate, and sherbet in succession while monitoring the stove display. Then, Ms. S reviewed the Cook's Collage, poured her standing count of water into the mixing bowl, and retrieved another count of water to add into the bowl. While stirring, Ms. S glanced at the Cook's Collage again and announced her recipe completion to the proctor without once having touched either soda bottles for this recipe as well. For Trial PSI, Ms. S followed the recipe in a similar sequence to Trial PS but now with additional alarm interruptions. She added powder, sugar, and nine counts of water before adding orange and pineapple concentrate. Then, Ms. S reviewed the Cook's Collage, opened the sherbet box, tapped the stove display, and walked to the sink to complete the water additions while monitoring the stove display and managing alarm interruptions. Immediately after adding the final water, Ms. S turned her attention with a whistle to adding the sherbet while still monitoring the stove and alarm interruptions. She glanced at the Cook's Collage and stove display before her final count of sherbet. Immediately afterwards, Ms. S announced her completion to the proctor without once having touched either soda bottles for this third recipe. It should be noted that Ms. S consistently proceeded to the sherbet ingredient immediatly after the juice concentrates without referring to the recipe in between nor afterwards. This deviation from her previous cooking routine did not permit Ms. S to confirm the next listed ingredient which incidentally was the missing soda ingredient. Ms. S explcitly reordered her recipe routine as a memory coping strategy to focus on a particular ingredient that she previously forgot whereas she offered no comments on using the Cook's Collage for subsequently forgotten ingredients; thereby, implying her own focused changes in routine limited her focused use of available memory cues.

6.8.2.2 Unavailable Additional Attention

When asked about his use of the Cook's Collage in Session 1's CSI trial, Mr. A commented, "Not particularly. I counted and looked at the recipe. I didn't have time to look at the aid." Video review of this cooking episode confirmed how Mr. A looked at the Cook's Collage during only two ingredients (e.g., sugar, butter); thereby, suggesting that he had unavailable additional attention to use the offered memory assistance. Further video review of Mr. A's visual attention pointed out his *tunnel vision* towards the recipe and the mixing bowl; thereby, limiting *voluntary* eye-glances toward the Cook's Collage (and the stove display).

Mr. A started this cookie recipe (i.e., his first cookie recipe with the Cook's Collage available) by focusing his attention to adding three (of the required five) counts of flour into the mixing bowl before being interrupted with a sounding alarm. He sat down his measuring cup leaving the flour container open, poked at the stove display, and attended to the alarm. Upon returning to the kitchen, Mr. A immediately poked at the stove display and retrieved the baking soda while reading the recipe and muttering "okie dokie." After adding the baking soda, Mr. A turned his attention to the recipe again and added the salt before another alarm sounded. He poked at the stove display and attended to the alarm. Upon returning to the kitchen, Mr. A looked at the Cook's Collage and then the recipe while muttering, "All right'.' Mr. A gingerly opened the butter which allowed him to monitor the stove display. Then, he turned to the recipe and Cook's Collage, and reached for the sugar container before being interrupted again. Returning from the alarm, Mr. A poked at the stove display, and reoriented himself to the cooking assignment by looking into the mixing bowl, at the Cook's Collage, and at the recipe while muttering, "Where are we? Well, I.Well, well, Ok." Then, Mr. A reached his measuring cup into the opened flour container but immediately corrected himself by opening the sugar container while rechecking the recipe before adding the sugar. Then, he read the recipe to add two counts of brown sugar and rechecked the recipe while slowly adding an additional count of brown sugar. The alarm sounded, pulling Mr. A out of the kitchen again. Upon return, Mr. A was whistling as he read the recipe and turned around in the direction of the refrigerator (perhaps for the egg as the next ingredient). However, the stove display caught his attention, so he tended to it. Then, the alarm sounded, so he attended to it. Mr. A was again whistling upon returning to the kitchen. He paused to look down into the mixing bowl and up at the recipe exclaiming, "Well..." Then, he added one (of the required four) count of vanilla and announced his completion to the proctor. Given my video observation and his interview comments, I concluded that Mr. A did not have additional attention amidst the alarm interruptions and stove monitoring to use the Cook's Collage during this cooking episode. However, it is important to add that Mr. A did come to have more available attention in his subsequent sessions to use the Cook's Collage; thereby, implying his initial unavailable attention as him choosing not to look out for additional help but instead to further focus on his own memory routine.

6.9 Summary: Study Findings Informing Thesis Claims

In this chapter, I presented the Repeated-Use Study and its resulting findings. I contributed the experimental protocol and analysis procedures as a systematic method in evaluating memory cues of memory for actions (in this case, ingredient additions). I reported resulting memory performances from six older adults to demonstrate that memory slips did occur. I recounted qualified use cases with the Cook's Collage to illustrate how the memory surrogate did assist memory recall for most ingredients, but I also showed how limitations in the Cook's Collage did not benefit a few ingredients. Lastly, I reported extenuating biases that deterred opportunities for memory assistance. I will further discuss these user experiences in Chapter 7 to point out emerging trends deserving future studies, but the purpose of this chapter was to present qualitative and quantitative study findings that defended the three claims of this thesis.

CHAPTER VII

CONCLUSIONS AND FUTURE WORK

In this thesis, I investigated how to support memory for actions in everyday cooking at home. Inside the kitchen of the Aware Home Residential Laboratory, I observed the coping strategies and resourceful memory aids that cooks devised as they added repeated amounts of the same ingredients day after day. I compared their perceived performances with their actual results. Discovering that people do forget and miscount ingredients, I built a technological aid I called the Cook's Collage (using a wizard of Oz simulation) as a visual summary to augment memory recall of repetitive actions. By studying the behavior and attitudes of participating cooks, I examined two central questions: 1) When presented with a novel memory surrogate, what biases deter people from using provided memory cues? and 2) Once people do interact with a memory surrogate, which design and implementation features provide effective memory support and which do not?

From my studies, I concluded that 1) Visually summarizing activities by capturing items used within the activity in the same physical surroundings can provide sufficient context in recalling memory for actions, 2) User interaction with accurate memory support that complements and supplements rather than interferes with memory practices, activity constraints, and environmental surroundings can effectively augment memory recall, and 3) Barriers to using provided memory support can include unawareness of memory need and predilection to own memory ability and routine.

I submit this dissertation to *demonstrate* how visual summaries (e.g., the Cook's Collage) augmented memory recall of repetitive actions (e.g., ingredient additions in everyday home cooking) as *one* in-depth *counter* example to predominant approaches of design, implementation, evaluation, and analysis for home technology and memory aids. I do not claim that my proposed approaches are paradigm shifts because I have yet to compare formally with related work even though my supporters and stakeholders are championing them as such. Still, I contribute the Cook's Collage to illustrate underlying *concepts* presented in the previous chapters and concluded in this final chapter. In each of the following four sections, I share my key "aha!" epiphanies from lessons learned that directed me away from conventional techniques. Based on previous work, I point out limitations of suggested alternatives offered by contrasting viewpoints, and I suggest opportunities for future work based on emerging findings from this work and related work. Lastly, I comment on the interdisciplinary skills that this applied research requires.

7.1 Redistributing Design

I contribute the Cook's Collage *display* as an example visual design that supports memory recall of repeated actions. Moreover, I contribute its underlying design concepts with the acronym *deja vu* as a framework for memory aids. In designing the memory surrogate, my key "aha!" realization was in reversing the *flow* of memory information and therefore the *control* of interaction. The predominant method to *engage* user experience is immersing the human *into* their environmental surroundings and into their intended tasks; thereby, enabling "smart" spaces to *guide* user assistance. Many "smart" kitchens (e.g., KitchenSense [67]) have numerous physically embedded sensors that track human activity to interpret, anticipate, and instruct the user in performing the next task from a predetermined list of desirable activities. For example, eyeCook [98] tracks the cook's eye gaze to infer which recipe instruction or ingredient description to read out loud next.

Instead of immersing the user into a "smart" space, I chose to distribute ephemeral and internal (memory) information *onto* the physical environment as an undemanding *background*; thereby, *deferring* to the “smart” human if and when to engage with the augmented space and with the purposed tasks. I wanted to support users by *freeing* them with minimal and fluid interactions so that they can also manage unpredictable distractions external to the immediate surroundings and immediate tasks.

Don Norman much more elegantly came to this same “aha!” realization and is promoting it as the future paradigm of designing human computer interaction by arguing,“But what if you decide to do something that the [smart] house thinks is bad for you, or perhaps simply wrong? ‘No,’ says the house, ‘that’s not the proper way to cook that. If you do it that way, I can’t be responsible for the result. Here, look at this cookbook. See? Don’t make me say ‘I told you so.’ ...The challenge is to add intelligent devices to our lives in a way that supports our activities, complements our skills, and adds to our pleasure, convenience, and accomplishments, but not to our stress [86].” In memory aid research, LoPresti, Mihailidis, and Kirsch came to a similar separation of user interaction designs in their survey of assistive technology for cognitive rehabilitation although with slightly different motivation from *long-term* effects. They defined prothesis as assistive devices (e.g., prosthetic limbs) that enhance or enable human ability and orthesis as assistive devices (e.g., crutches) that correct or relieve weakened human ability by temporary compensation. I likened prothesis to immersive user experiences and orthesis to what I described above as *supportive* user experiences.

Both styles of assistance have their merits for certain users and in certain situations as do both styles of user interaction. I am not concluding one as more effective or more desirable than the other, but I am pointing out ample opportunity in creating orthetic *technology* beyond the existing three examples (i.e., this Cook’s Collage, HomeNote [97], and recommendation systems) in contrast to the many already existing prothetic technologies (e.g., wizard tutorials, car navigation systems).

7.1.1 Not Reinventing the Squared Wheel

In designing the Cook's Collage, I chose *not* to pursue suggested alternatives based on my understanding of *what* supports memory recall within everyday activities that I gleaned from the long history of memory aid research. I also chose against offered options because Norman advised that "Everyday activities must usually be done relatively *quickly*, often *simultaneously* of other activities. Neither time nor mental resources may be available. As a result, everyday activities structure themselves so as to *minimize conscious* mental activity, which means they must *minimize planning* (and especially any planning with extensive looking ahead and backing up) and mental computation [85]." Because the Cook's Collage was able to support these characteristics of everyday activity, I conclude that Cook's Collage design succeeded in contrast to the following *conventional* design suggestions that do not address these characteristics.

7.1.1.1 Why Automated?

Why not have the user adhere to an a priori memory protocol such as speaking aloud mental notes to be remembered or recorded by a memory aid. This would be a much simpler solution than the activity monitoring required of the wizard of Oz to generate the Cook's Collage display. However, prior surveys of memory strategies that require learning or diligence in maintaining for use were shown to be used infrequently by young people [39] and by memory experts who knew the memory benefits of using these memory strategies [87]. In my experiments, I noticed memory strategies that participants employed to mark their progress (e.g., laying measuring utensil beside current ingredient, counting with their fingers), but the same participants frustratingly could not *maintain* their protocol *consistently* amidst distractions. Thus, I chose to automate the Cook's Collage so as to relieve the user from the burden of learning and maintaining a memory protocol.

7.1.1.2 Why Photographs?

Why not show text to spell out clearly and simply the ingredients by name? I used photographs because an image is worth a thousand words. Not only does a photograph show the content (i.e., identified ingredient), it also shows the *context* that reinforces believability (i.e., *my* hand *caught* in the act of adding this ingredient here). Prior studies with text printouts from event logs could not convince office workers of where and when they transferred documents against counter beliefs of machine *error* [31]. A similar argument could be made against *trusting* checklists checklists by an automated but faulty tracking system.

Why not show video replaying forgotten actions like most of capture and access applications and life-logging applications (e.g., [34, 47, 58, 78])? Lahlou and Kirsh discovered that video replay (i.e., twenty second buffer that can be halted at user's discretion) *hindered* office workers in resuming their task of transferring handwritten corrections from a physical document into a text editor on the computer after being interrupted [63]. They demonstrated that video replay as a recovery device prolonged time required to complete the assigned activity without significantly improving the activity performance. However, video replay might be a design extension worth exploring as future work given the photographs of the Cook's Collage to index video segments. After all, video is a variable dimension open for future exploration in my conceptual framework of deja vu displays.

7.1.1.3 Why Visual?

Why not have speech inquiry to an intelligent agent? While I am not opposed to intelligent agents assisting memory recall (e.g., remembrance agent [90]), I caution the social stigma of *noticeably* asking for help for people who do not *want* help. Based on interview comments from my older adult participants, they wanted to appear not *needing* assistance.

Why not provide sound or some modality other than vision that does not compete with user attention of the ongoing activity? This was my initial design approach before I learned that cognitive failures most commonly occur because of divided attention [73]; therefore, providing memory cues in a parallel modality will divide user attention and thereby likely cause memory slips. In contrast, using the same modality allows for *necessary* shifts in user attention to confirm memory recall before resuming the activity.

7.1.2 Emerging Design Extras

With older adults using the Cook's Collage, a few additional design features would have added even more value. Because the display was limited to six images, adding a user interaction to page back may have helped cooks who tried using the Cook's Collage at the end of their recipes to verify all ingredient additions. Adding an alerting feature to prevent or undo a recipe mistake may have helped cooks who over-counted ingredient additions or missed ingredients completely. Although such *instructional* design is antithetical to the Cook's Collage as a memory *surrogate* fostering creatively open-ended cooking, the cost of forgetting may warrant a more proactive memory aid different from the Cook's Collage.

7.2 Remeasuring Aid

I contribute user experiences with the Cook's Collage as illustrative case studies under various conditions of use and non-use. Moreover, I contribute my underlying measurements of success for the Cook's Collage as an augmentative technology. In evaluating the memory surrogate, my key "aha!" realization was in measuring *individual usage* and not *memory broadly*. The predominant measurement of success for a memory aid is eradicating memory failures; thereby, *correcting* the memory *problem*. Instead, I measured success by *promoting* memory *support* based from my key "aha!" realization that *minimizing* cognitive failures (i.e., not being able to do what is *normally* within one's own ability) meant *maintaining* under distressful situations rather than in *improving* memory recall under general conditions. By considering the numerous opportunities for *supporting* memory recall rather than the few opportunities for *fixing* memory failures, I was able to comparatively investigate individual circumstances that rendered the Cook's Collage more or less effective in supporting memory recall. Situations in which cooks *unsuccessfully* remembered ingredient counts by not using the Cook's Collage were actually *successful* illustrations of the human *choice* not to rely on technology and of the machine's *unimposing* assistance on the ongoing activity. Argued more eloquently by Norman, "Augmentative tools are comforting, for they leave the decisions about activities to people. Thus, we can take them or leave them, choosing those that we feel aid our lives, ignoring those that do not. Moreover, because these are voluntary, different people can make different choices, so that people can choose whatever mix of technology suits their life style [86]." I believe further work is needed to define qualified measures of success for augmentative technology.

7.2.1 Why Not Corrective?

Why not have the Cook's Collage provide proactive assistance to correct for miscounted and forgotten ingredients? I chose not to follow this approach because I felt it resembled too closely activity automation of manufacturing an exact product; thereby, removing too much from the human experience of creativity, engagement, and personal achievement. I created the Cook's Collage for people who enjoy cooking to use and not people who conveniently purchase ready-made food. Also, I felt that more directly correcting for memory slips would increase human dependency on machine assistance; thereby, atrophying *human* memory recall even with overall improved *activity* performance. Hence, I needed to be clear and exact about my units of measurements and how I defined success for the Cook's Collage as a supportive memory aid and not a corrective cooking aid.

For those who enjoy food, a new direction for celebratory technology have been recently proposed for promoting human-food interaction [37]. For those who enjoy cooking, there has been an increasing variety of digital applications such as ambient cooking entertainment [56], online sharing of recipes [103], and nutrition monitoring [22]. In line with Roger's advocacy of moving beyond the conventional goals of *fixing* existing human problems and slips in producing a desired product (in this case, food), these example applications promote the creativity and engagement of human experiences with technology in a *supportive* not corrective role. Likewise, my case studies of how people came to use the Cook's Collage demonstrated how supportive not corrective technology can add value into human experiences. I am not concluding that traditional use of corrective aids are no longer valid or worth exploring further, but I am pointing out ample opportunity in creating supportive aids.

7.2.2 Why Not Assistive?

There are many systems that assist novice cooks in learning new recipes. For example, eyeCook [98] tracks the cooks eye gaze to infer which recipe instruction or ingredient description to read out loud next. Another kitchen system [99] uses foot panels along the bottom kitchen cabinets for the user to navigate explicitly through recipe instructions. VERA provides pictorial step-by-step recipe guides for cooks with language impairments [104]. As *cooking* aids, these systems focused on navigating the cook through to-be completed recipe steps whereas the Cooks Collage focused on recalling already completed recipe steps as a *memory* aid.

From emerging user experiences with the Cook's Collage, some particularly forgetful cooks would have benefited from more guided assistance. As future work, the Cook's Collage could be extended as a redesign and remeasurement for different sets of users (e.g., Alzheimer's and dementia patients).

7.3 Recalibrating Technology

I contribute the wizard of Oz simulation as an example enabler of sufficient activity monitoring for the Cook's Collage. Moreover, I contribute its underlying engineering principles of contextualized monitoring as sufficient requirements for memory recall applications. The predominant methods for wizard of Oz to determine user requirements are either simulating the ideal technology or informing usage grammars (e.g., speech phrases for voice interaction [62]). Instead, I used the wizard of Oz as a testbed to gauge quality of service among individual differences; thereby, investigating how smart was enough. In improving recognition accuracy and monitoring speed for the wizard of Oz, my key "aha!" realization was in calibrating the technical requirements *relative* to the user's *perspective*. That is, I leveraged the value of shared visual information to alleviate recognition requirements for task-oriented recall. I demonstrated that recognition (rather than identification) of objects and that repetitions of actions (rather than measurements of contents) was sufficient; thereby, establishing points of diminishing return on future technical investments (in achieving identification and measurement) in adding value to the user experience.

However, future investment in technology to improve quality of service for the Cook's Collage would improve the user experience. My resulting performance achieved 90% overall accuracy (98% usage accuracy) and 1-19 second delay. As future work, alternative wizard of Oz implementations with different visual interfaces than those I created for myself as the human operator can be explored to improve upon my performance levels. Machine learning algorithms can also be explored and compared to my wizard of Oz simulation.

7.4 Recreating Breakdown

I contribute an indirect simulation study (e.g., Repeated-Use Study) as an experimental method that repeatedly recreated the memory phenomena of forgetting recently performed actions. Moreover, I contributed a comparative study of *perceived* memory needs with *actual* memory performances. In addressing the memory *need*, my key “aha!” realization was in directly *disabusing* participating cooks of their *presumed* memory proficiency. That is, I chose more expeditious methods to confront the memory introspection paradox (i.e., omissions from unawareness of memory slips and commissions from remembering incorrectly [44]).

As future work, more ecologically valid studies can evaluate the Cook’s Collage and everyday cooking at home. Perhaps the wizard of Oz system can become a “call center” that monitors audio and video of meal preparations in neighboring home kitchens as a field deployment study for the Cook’s Collage. Without the Cook’s Collage, this same “call center” can become a monitoring system that only captures (and not intervene with) naturally occurring memory slips in everyday home cooking. Results from these more ecologically valid studies can be compared with results from my laboratory studies.

7.5 Summary: Regrouping Skills

In this chapter, I summarized my contributions in this dissertation. I shared my key “aha!” realizations that propelled me to reach demonstrable conclusions regarding display design of visual summaries, wizard of Oz simulation for sufficient activity monitoring, indirect simulation procedures for recreating memory slips, and qualified case studies of memory support. I also recommended future opportunities in extending this research, but my advice to future efforts would be remiss without commenting on the *mulit-disciplinary* skills necessary to complete this project.

Applications of “end-to-end” services such as the Cook’s Collage require a varied skill set. Fortunately, my interdisciplinary training prepared me for most of the work, and my motley crew of colleagues assisted me with their valuable skills for the rest. With my software engineering background, I coded every programming component for the wizard of Oz and for the simulated distractions (e.g., animated stove display, alarm key pad) in the Repeated-Use Study. With my human-computer interaction education, I designed the Cook's Collage display for the cook and the visual interfaces for the wizard of Oz. With my "do-it-yourself" enthusiasm and colleague with carpentry skills, we mounted the physical infrastructure (e.g., flat panel display, cameras) of the Cook's Collage system in the Aware Home kitchen laboratory. Consulting with experimental design experts, I piloted many various study procedures and analysis parameters that became the Repeated-Use Study presented in this document. Consulting with experts in computational perception and wizard of Oz prototyping, I custom-built a wizard of Oz system that simulated the Cook's Collage to evaluate the user experience. As the lead investigator of this project, I organically grew this applied research from a simple idea (see usage scenario from first chapter) into an "end-to-end" proof of concept demonstration. In my first attendance at a gerontechnology conference [5], my key "aha!" realization was in appreciating the competitive *advantage* from having assembled an interdisciplinary team of skilled experts. Projects in health care informatics, cognitive aging, etc. conducted within isolated departments were struggling with challenges that more integrated teams (e.g., [28, 93]) had mastered. Thus, I recommend future efforts in home technology and memory aid research to be conducted within interdisciplinary (or at least between collaborative) teams.

APPENDIX A

REPEATED-USE STUDY PROTOCOL

The experimental protocol #H04171 approved by IRB (Institutional Review Board for Human Subjects) was an amendment upon the experimental protocol #H01127 to create laboratory procedures for the Repeated Use Study. The following sections comprise of the paperwork submitted for IRB approval via the university online database. I submitted additional information via online forms that I do not include here.

- cover letter, with amendment
- recruitment procedure
- consent form
- list of interview questions
- written questionnaires

A.1 Cover Letter

We have designed a preliminary system prototype that helps people better multitask, or resume their tasks after interruptions. In this experiment, we want to evaluate if and how the prototype is successful and how over time people change and/or retain their strategies for using the system.

The system prototype consists of a flat-panel display showing a dynamic collage of recent activity in the kitchen collected from the systems cameras. The system has PC cameras positioned around the kitchen to take close-up hand snapshots.

The principal investigator and the system operator will meet the subject in the kitchen of the Aware Home, located on corner of Center and 10th street of campus, explain the experimental procedure, and obtain informed consent (or assent) from the volunteering subject. Then, the experiment will be conducted as follows.

The subject will be asked to do a main task making food preparations by following a recipe. During which, he/she will be asked to monitor a computer program that simulates the controls on a standard stove. The subject will also be interrupted by other matters typical in a home. He/she will attend to them as they arise, and otherwise keep a comfortable pace of cooking. The session will involve only the food preparations (mixing ingredients) and will end before any heating to preempt any potential fire hazards. The investigator will observe the subject interacting with the system prototype within the AwareHome in addition to monitoring the subject to safeguard against any foreseeable cooking hazards. The cooking session will be videotaped from a standing video camera at one corner of the kitchen. This recording will be used for research purposes only, to be viewed by the primary investigator. The system operator will be seated in another separate room. Her role is just to operate the system. She will only have the system prototype cameras to look onto the subjects actions.

This study is interested in assessing how subjects strategies for using the system prototype change over time and how their knowledge of the system is retained following time spent away from the system. To investigate this, the subjects will be asked to attend four experimental sessions over a two week period. The days and times of these sessions will be coordinated based on what is most convenient for the subject. All experimental sessions will follow the same procedure detailed above.

We are interested in looking at how older adults use the system as compared to younger adults. We thus will recruit subjects from two areas. Older adults will be recruited by calling individuals in the older adults subject pool coordinated by the cognitive aging lab in the School of Psychology at Georgia Tech. We will give potential subjects an overview of the study and the time commitment and ask if they would like to participate. Younger adults will be recruited through the AwareHome families subject pool that is currently being formed. All subjects will be compensated for their participation.

A.1.1 Amendment

We would like to modify our procedure to include both an experimental pre-session and post-session. The pre-session will consist of a one and a half hour session in which the participants will do the four described cooking tasks (same tasks as in the other sessions) but without the Cooks Collage memory aid available to them. The purpose of adding this session is to obtain a baseline measure of cooking performance for each participant, that we can later compare with performance in sessions when the memory aid is available to the participants. The post-session will be part of the final experimental session. After completing the cooking tasks for the fourth time with the memory aid, participants will perform the four cooking tasks one last time, but without the cooking aid. The purpose of this post-session is to observe whether participants have become reliant on the cooking aid over the four sessions.

Thus, we propose having a total of 5 sessions, as opposed to the 4 sessions proposed in the original protocol. The 5 sessions will be as follows:

Session 1: Pre-session. Four cooking trials performed without the memory aid. Session 2: First session with the memory aid. Four cooking trials are performed. Session 3: Second session with the memory aid. Four cooking trials are performed. Session 4: Third session with the memory aid. Four cooking trials are performed. Session 5: Fourth session with the memory aid. Four cooking trials are performed. Then, a post-session where four cooking trials are performed without the aid.

Finally, at the conclusion of each session we will be giving each participant feedback on how they performed by telling them whether they forgot to add an ingredient or forgot a step, and what percentage of alerts they addressed accurately on the monitoring (dual) task and the interruptions task. The purpose of adding this feedback is to give participants an idea of how they did and a goal for improving in the next session.

Following each task in the pre-session and post-session, the following interview and survey questions will be asked. Note that these are just a subset of the questions that were submitted with the original protocol for this study.

A.2 Recruiting: Calling Script

Begin the conversation with: This is Gina Calcaterra calling from the Psychology department at the Georgia Institute of Technology. Your name was on our list of people interested in participating in some of our research projects. We have a new project underway and I want to see if you would be interested in participating. We are conducting a preliminary evaluation of a system prototype that seeks to help people handle interruptions while cooking in a home setting.

I just need to find out how old you are: Are you between the ages of 65 and 75?

- If not between 65 and 75: I'm sorry but we need to get people between those ages for this particular study. Thanks for your time.
- If they are between 65 and 75: Great, youre in the age group we need.

The study will actually take place in the Aware Home. We will have to travel up and down one flight of stairs. The actual study will be videotaped to aid the scientists there in their design of new technologies similar to our cooking aid prototype, but only your hands will be videotaped.

The study will be spread out over five sessions over a two week period, each lasting approximately one hour to ninety minutes each. You will receive $5 per hour for your participation, and in addition to the payment, we will also provide convenient parking for you.

Are you interested in participating?

- If no: Thank you anyway for your time, and we do appreciate your past participation.
- If yes: Great. We will call you and remind you a couple days before your scheduled time. In addition we will mail you a map and directions about where to park and how to get to the Aware Home.

A.2.1 Schedule

Let me give you our telephone number in case you think of any questions later on. My name is Gina Calcaterra and I can be reached at 404-894-8186 during the day and 404-603-8707 in the evening. If no one answers, please leave a message and I will call you back. Thank you for you time, and I look forward to your visit.

A.2.2 Online Flyer

To recruit younger adults who participated in the Repeated-Use Study, we used Figure 21 as an online advertisement.

Cook's Collage

Do you cook? Have you ever had trouble remembering how many times you've added an ingredient because you were distracted while cooking a recipe? Have you ever been interrupted while cooking and forgotten what you were doing?

what is cook's collage

Cook's Collage is a memory aid for cooks. Cooking is a physical activity that is subject to distractions and interruptions. Cook's Collage provides a visual summary of recent cooking activity along a kitchen countertop.

We are looking for people to participate in a research study to evaluate Cook's Collage that involves doing some basic cooking tasks. The research study will consist of 5 one hour to 90 minute sessions. You will be compensated in return for your participation.

If you are interested in participating in this study, or would like more information please contact:

Gina Calcaterra at (404) 603-8707
E-mail ginac@cc.gatech.edu.

Figure 21: Recruitment Flyer for Repeated-Use Study

A.3 Consent Form

Consent Form
Georgia Institute of Technology
College of Computing

1) **Title of Research Project:** Cooking interruptions evaluation and retention study.

2) **Principal Investigators:** Elizabeth Mynatt, Quan T. Tran, Gina Calcaterra.

3) **Purpose of Research:** You are being asked to participate in a preliminary evaluation of a system prototype that seeks to help people handle interruptions while cooking in a home setting. Each experimental session will take between one to two hours.

4) **Procedures:** In this experiment, you will be asked to make food preparations by following a prescribed recipe. The recipe will involve only preparing food, no cutting or heating will be involved. During which, you might be interrupted by other matters typical in a home. In one case you will also be asked to monitor a computer-simulation of a stove. Please attend to interruptions as they arise, and otherwise keep a comfortable pace of cooking. You will be given a form that asks demographic information and you will be interviewed throughout about your experience. The experiment will take place in the AwareHome, with the primary investigator instructing and observing the subject, and a system operator controlling the system prototype. Each participant will be asked to participate in five sessions that last between one to two hours over a two week period. The cooking session will be videotaped for recording and research purposes only, to be viewed by the primary investigator. Thirty subjects are expected to participate.

5) **Foreseeable Risks or Discomforts:** Minimal, that is, the probability and magnitude of harm or discomfort anticipated in this research are not greater than those ordinarily encountered in daily life during the performance of routine physical/psychological examinations or household chores.

6) **Benefits:** There are no direct benefits to you, however we hope to find out more about the prototype that we are developing.

7) **Compensation:** You will be compensated $5/hour for your participation in this study.

8) **Confidentiality:** The following procedures will be followed to keep your personal information confidential in this study: The data that is collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

   The evaluation session will be recorded for future analysis. The experimenters will use the video and auditory recordings for verification of key findings and further data analysis. The recordings will be securely stored in the Aware Home facility and will be kept for archival purposes. The recordings will be used to verify human performance observations and establish a record of the test session. Only the investigators for this study will have access to the recordings.

   To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB will review study records. The Office of Human Research Protections may also look at study records.

9) **Injury/Adverse Reactions:** Reports of injury or reaction should be made to Quan Tran at 404-385-1102. Neither the Georgia Institute of Technology nor the principal investigator has made provision for payment of costs associated with any injury resulting from participation in this study.

APPROVED *Consent Form Approved by Georgia Tech IRB: December 8, 2004 - September 19, 2005*

10) **Contact Person:** If you have questions about the research, call or write Quan Tran at 404-385-1102; College of Computing; Georgia Institute of Technology, Atlanta, GA 30332-0280.

11) **Voluntary Participation/Withdraw:** You have rights as a research volunteer. Taking part in this study is completely voluntary. If you do not take part, you will have no penalty. You may stop taking part in this study at any time with no penalty. If you have any questions about my rights as a research volunteer, call or write:

    Melanie Clark
    Office of Sponsored Programs
    Georgia Institute of Technology
    Atlanta, Georgia 30332-0420
    Voice 404-894-6942 Fax 404-894-5285

12) **Signatures:** A copy of this form will be given to you. Your signature below indicates that the researchers have answered all of your questions (if you have had any) to your satisfaction and that you consent to volunteer for this study.

____________________________ __________
Subject's Signature Date

____________________________ __________
Investigator's Signature Date

Name (please print): ________________________

Figure 22: Consent Form for Repeated-Use Study

A.4 Interview Questions

Participant's Background:

- How often do you cook? A) Every day, B) couple times a week, C) once a week, D) once in a while, E) I never cook, F) Other
- How often do you multitask while preparing food/drink in the kitchen?
- If you do multitask, what are the other tasks that you do while cooking?

After the initial play period:

- Now, I want you to suppose that your friend comes over and is curious about this new product you have in your kitchen. How would you explain to your friend how to use this system for cooking a recipe?

- What particular suggestions would you give your friend for how to use the system?

After Each Trial:

- Did you have a strategy for adding the ingredients? If so, could you describe your strategy to me?
- On a scale of 1 to 5, do you think you forgot to add any ingredients? If so, what? (1 = definitely not, 3 = maybe, 5 = I'm sure I did)
- On a scale of 1 to 5, o you think you missed a step (added too few or too many scoops of an ingredient)? If so, which ingredient? (1 = definitely not, 3 = maybe, 5 = I'm sure I did)
- On a scale of 1 to 5, how much did you use the aid while performing this task? Were there any times when you used the display more than others? If so, when?

At the End of Each Session:

- Given the recipe you just did, how would you explain to your friend how to use the system to complete this particular task?
- Of the 4 cooking tasks you performed today, which one, if any, did you find the display most useful for? Why?

At the End of the Fourth (i.e., final) Session:

- Based on the experiences youve had here these past 2 weeks, what do you think of the system overall? Would you use it in your home? If not, what improvements could be made that would make you want to use it?

A.5 Written Questionnaires

Demographics

Name: ☐ Dr. ☐ Mr. ☐ Mrs. ☐ Ms. ☐ Miss ____
First name Middle Initial Last Name

Date of Birth: _____/_____/_____
Month Day Year

Phone #: Home (_____) _______-_________

Gender: ☐1 Male ☐2 Female

Work (_____) _______-_________

Main Address:

____
Street Apartment #

____
City State Zip Code

____
Email Address

Second Address (part of the year):

____
Street Apartment #

____
City State Zip Code

When are you at this address? ______________

1. **Education completed (check highest level)**
   - ☐1 Less than high school graduate (highest grade completed? ________)
   - ☐2 High school graduate/G.E.D.
   - ☐3 Some college, or trade, technical, or business school (how many years? _________)
   - ☐4 Bachelor's degree
   - ☐5 Some graduate work (how many years? _____)
   - ☐6 Master's degree
   - ☐7 M.D., J.D., Ph.D., other advanced degree

2. **Current marital status (check one)**
   - ☐1 Single
   - ☐2 Married
   - ☐3 Separated
   - ☐4 Divorced
   - ☐5 Widowed
   - ☐6 Other (please specify ________________)

3. **Race/ethnicity**
   - ☐1 Black/African American
   - ☐2 Asian American/Pacific Islander
   - ☐3 White/Caucasian
   - ☐4 Hispanic/Latino
   - ☐5 American Indian/Alaskan Native
   - ☐6 Multiracial (please specify ____________)
   - ☐7 Other (please specify ________________)

4. **In which type of housing do you live?**
   - ☐1 Residence hall/College dormitory
   - ☐2 House/Apartment/Condominium
   - ☐3 Senior housing (independent)
   - ☐4 Assisted living
   - ☐5 Nursing home
   - ☐6 Relative's home
   - ☐7 Other (please specify ________________)

5. Do you live alone a majority of the year?

- ☐1 Yes
- ☐2 No

6. What is your primary language?

- ☐1 English
- ☐2 Spanish
- ☐3 French
- ☐4 Creole
- ☐5 Portuguese
- ☐6 Other __________

7. Occupational status (check all that apply)

- ☐1 Working full-time
- ☐2 Working part-time
- ☐3 Student
- ☐4 Homemaker
- ☐5 Retired
- ☐6 Volunteer worker
- ☐7 Seeking employment, laid off, etc.
- ☐8 Leave of absence
- ☐9 Other (please specify):

8. What is your current occupation? ________________________________

Figure 23: Demographic Background Questionnaire

Trust Questionnaire to be given after each trial:

Participant # _____

Please rate the extent to which you agree with the following statements. **Your ratings should only reflect your experience with the cooking aid.**

1. I can trust the cooking aid.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

2. The information displayed by the cooking aid is provided in a timely manner.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

3. I am suspicious of the cooking aid's output.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

4. I am confident in the cooking aid.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

5. The cooking aid provides accurate information.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

6. The information provided by the cooking aid is reliable.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

7. I feel that I am familiar with the cooking aid.

+---------+---------+---------+---------+---------+---------+
1 2 3 4 5 6 7
not at all very much

8. Please indicate how reliable you think the cooking aid is (write in a number)

0% -- 100%
Reliable Reliable

Figure 24: User Trust in Cook's Collage

Subject ID __ - __ - __ __ __ Trial _______

To be given after each session:

Please consider all of the trials you have completed while answering these questions.

MENTAL DEMAND
How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Low **High**

PHYSICAL DEMAND
How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low **High**

TEMPORAL DEMAND
How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was that pace slow and leisurely or rapid and frantic?

Low **High**

PERFORMANCE
How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Good **Poor**

EFFORT
How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low **High**

FRUSTRATION LEVEL
How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Low **High**

Figure 25: TLX of Session Trials

RELIABILITY QUESTIONS (after each session)

Please consider all of the trials you have completed while answering these questions.

Overall, how much do you trust the status indicators?

1	2	3	4	5	6	7
Not at all						Completely

To what extent can you count on the status indicators to do their job?

1	2	3	4	5	6	7
Not at all						Completely

The status indicators always notified you on what you were supposed to do

1	2	3	4	5	6	7
Disagree						Agree

The status indicators are reliable

1	2	3	4	5	6	7
Disagree						Agree

How reliable do you think the status indicators have been up until now?

0% reliable	25% reliable	50% reliable	75% reliable	100% reliable

Figure 26: Reliability of Cook's Collage

APPENDIX B

DUAL TASK STUDY PROTOCOL

As Table 23 shows, the study consisted of four trial conditions. The Cook's Collage was provided for the fourth (i.e., final) trial condition; thereby, evaluating only first-time use (as opposed to repeated-use in the main study reported in this thesis). Participants performed the primary assignment of learning how to count in a foreign language by listening to audio tapes and repeating aloud along with the language tapes that repetitively drilled the five foreign digits with their corresponding English translations. The secondary assignment consisted of a punch recipe with repeated measurements prefaced in Figure 4. The participants were asked to pace their cooking to complete the punch recipe as the language lesson ended; thereby simulating a dual task situation.

Table 23: Example sequence of condition comparisons within participant

Trial Condition	Language Assignment	Cooking Assignment	Cook's Collage
1. baseline	Chinese 1-5	none	not applicable
2. control	Chinese 6-10	punch recipe	not available
3. basline	Vietnamese 1-5	none	not applicable
4. test	Vietnamese 6-10	punch recipe	availabe

B.1 Study Participants

22 younger adults (14 male, 8 female) of ages 23-51 participated in this study. All were graduate students from the College of Computing at Georgia Tech and were screened to ensure no prior knowledge of how to count to ten in Chinese-Mandarin or Vietnamese.

B.2 Procedure: Script

This experiment examines how people concentrate on language tapes while multitasking. This session consists of 4 separate conditions, each about 6 minutes. The entire experiment takes about 30-45 minutes.

Your main task is learning how to count to ten, five digits at a time, by using a two-minute language tape drill. Tape loops once, so total length is 4 minutes. Please follow along with the tape instructions. After each counting session, you will be quizzed over the numbers you just learned. Your secondary task is preparing punch by recipe which we will discuss later.

(pointing to Cooks Collage display) This is the prototype we will be testing in this experiment. It presents a dynamic synopsis of recent activity within a room such as this kitchen. (pointing out details of display) It presents six snapshots of recent past actions in relative time sequence, the most recent one being the one highlighted. Multiple steps that are being repeated are annotated with numbers. Please make sure to refer to the display often to get a running visual summary of what you just did (make sure they try to use display).

(pointing out cameras) The snapshots are taken from these cameras - notice that it takes close-up hand shots on the counters only. You can use either your right or left hand to scoop in ingredients. You can move the ingredients around, but try not to place them in front of the cameras. Do not move punch bowl.

The particular displayed pictures are selected by a wizard, operating a computer in another room. There is a pinhole camera to record your eye movements around the Collage, recipe, and the countertops. To archive this study, there is a standing handheld camera to record this cooking session.

(give consent form- explains all recording devices, confidential code name).

(after language task condition, pointing to recipe, ingredients) You can add ingredients in any order, but do pace this task so that you finish when the language

Consent Form
Georgia Institute of Technology
College of Computing

1) **Title of Research Project:** Cooking interruptions evaluation.

2) **Principal Investigators:** Elizabeth D. Mynatt, Quan T. Tran.

3) **Purpose of Research:** You are being asked to participate in a naturalistic scenario in a home setting while performing everyday household tasks. You are also being asked to utilize a potential memory aid that presents a visual summary of your most recent actions within a prefixed setting.

4) **Procedures:** In this experiment, you will be tasked to make food preparations by following a prescribed recipe. During which, you might be interrupted by other matters typical in a home. Please attend to them as they arise, and otherwise keep a comfortable pace of cooking. The experiment will take place in the AwareHome. The cooking session will be videotaped for archiving and research purposes only, to be viewed by the primary investigator.

5) **Foreseeable Risks or Discomforts:** The risks to you by participating in this study are minimal and are not greater than those you would encounter while cooking in your own kitchen.

6) **Benefits:** There are no direct benefit to you by participating; however, your participation may provide additional knowledge about the domain being investigated.

7) **Compensation:** You will not be paid for your participation and there is no cost to you.

8) **Confidentiality:** The following procedures will be followed to keep your personal information confidential in this study. The data that is collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code number rather than by name. Video footage and other stated recorded data will be filed digitally on a local computer server to be accessed by the study staff for archival purposes only. Your name and any other fact that might point to you will not appear when results of this study are presented or published. To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB will review study records.

10) **Financial Disclosure:** Not applicable.

11) **Injury/Adverse Reactions:** Reports of injury or reaction should be made to Elizabeth Mynatt at 404-385-1102. Neither the Georgia Institute of Technology nor the principal investigator has made provision for payment of costs associated with any injury resulting from participation in this study.

12) **Contact Person:** If you have questions about the research, call or write Elizabeth Mynatt at 404-385-1102; College of Computing; Georgia Institute of Technology, Atlanta, GA 30332-0280.

13) **Voluntary Participation/Withdraw:** You have rights as a research volunteer. Taking part in this study is completely voluntary. If you do not take part, you will have no penalty. You may stop taking part in this study at any time with no penalty. If you have any questions about my rights as a research volunteer, call or write:

Compliance Manager
Office of Research Compliance
Georgia Institute of Technology
Atlanta, Georgia 30332-0420
Voice 404-894-6942 Fax 404-894-5285

14) **Signatures:** A copy of this form will be given to you upon request. Your signature below indicates that the researchers have answered all of your questions (if you have had any) to your satisfaction and that you consent to volunteer for this study.

Date		Investigator's Signature
________		______________________________
Date	**Name (please print)**	**Subject's Signature**
________	____________________	______________________________
________	____________________	______________________________
________	____________________	______________________________
________	____________________	______________________________
________	____________________	______________________________

Figure 27: Consent Form for Dual Task Study

tape finishes. Remember, use loop as halfway point to pace yourself Your utensils are this 1/3 cup for orange juice, water from tap, soda, ice from bucket; this plastic scoop for powder; and this tiny scoop for sugar. To help the wizard follow what you are adding, either use long fluid movements while adding each ingredient or hover slightly above the ingredient and the bowl with each addition. Also, the display has a noticeable update delay (about 5 seconds but it varies), so adjust how you use the display accordingly.

B.3 Language Interview

"Count for me. This test the number order and pronunciation.

Pick 2 digits out of sequence that the participant was hesitant about to ask for translation. (e.g., "What is 4? What is 2?")

B.4 Language Questionnaire

Survey: Vietnamese 1-5

Rate the pace of the audio tape: too fast just right too slow

Check the numbers you were able to learn and remember. For the ones you did not remember, please explain why.

______ 1 ____

______ 2 ____

______ 3 ____

______ 4 ____

______ 5 ____

Figure 28: Survey of Vietnamese 1-5

Survey: Vietnamese 6-10

Rate the pace of the audio tape: too fast just right too slow

Check the numbers you were able to learn and remember. For the ones you did not remember, please explain why.

______ 6 ____

______ 7 ____

______ 8 ____

______ 9 ____

______ 10 ____

Figure 29: Survey of Vietnamese 6-10

Survey: Chinese 1-5

Rate the pace of the audio tape: too fast just right too slow

Check the numbers you were able to learn and remember. For the ones you did not remember, please explain why.

______ 1 ____

______ 2 ____

______ 3 ____

______ 4 ____

______ 5 ____

Figure 30: Survey of Chinese 1-5

Survey: Chinese 6-10

Rate the pace of the audio tape: too fast just right too slow

Check the numbers you were able to learn and remember. For the ones you did not remember, please explain why.

______ 6 ____

______ 7 ____

______ 8 ____

______ 9 ____

______ 10 ____

Figure 31: Survey of Chinese 6-10

Survey: Learning foreign language via language tapes

Have you ever known how to count to 10 in Chinese? _____ no _____ yes

Have you ever known how to count to 10 in Vietnamese? _____ no _____ yes

Have you ever used audio tapes to learn a foreign language?
_____ no

_____ yes, for languages: ____

How often do you multitask while listening to language tapes? _____%
What are these other tasks?

____

How often do you multitask while preparing food/drink in the kitchen? _____%
What are these other tasks?

____

Figure 32: Survey Form of Foreign Language Tapes

B.5 Punch Task Interview

“Do you think you forgot an ingredient? “Do you think you missed a step? “id you have a counting strategy? What were they?

B.6 Cook’s Collage Interview

“Do you trust the accuracy of the display? “Did the display change your counting strategy?

APPENDIX C

INTERRUPTION STUDY PROTOCOL

16 younger adults (10 male, 6 female) of ages 17-19 participated in this study. All were undergraduate students enrolled in a Psychology class at Georgia Tech, volunteering to my advertisement that specifically required them "to prepare cookie dough" although a few expressed difficulty in understanding the recipe instructions.

C.1 Study Participants

These participants completed their cooking assignment during which four differing interruptions at potentially problematic points within the cookie recipe occurred (see Table 24). A control group of 4 participants was not provided with the Cook's Collage (i.e., version 1.0), but the remaining 12 participants did have the memory aid available to use.

C.2 Procedure: Script

Your friend is nursing a sprained ankle injury and is moping at home watching a football game. Youve decided to come over and cheer him up by making him cookies and keeping him company. Your main task is to make cookies. During this task; however, you might be interrupted by your friend. Please be attentive and courteous to your friend as he asks for things, but otherwise keep a comfortable pace of cooking.

Each cook was then introduced and acclimated to the kitchen and the system prototype. The cooks were told to expect interruptions, but were not cautioned further on what particular interruptions to expect or when to expect them. The sequence of the interruptions listed in Table 24 was chosen at random per experiment for controllability between subjects.

Table 24: Surveying Types of Interruption

Interrupting Interjection	Location	Length	Stress	Timing within Recipe
1. "Pardon my reach."	same	short	low	while ingredient #1
2. "Oops- I need clean up!"	outside	short	low	while sugar
3. "Hey- let's talk."	same	long	high	after ingredient #2
4. "Help! TV broke!"	outside	long	high	while egg

In order to provide strong evidence whether interruptions do cause memory slips for cooks while cooking, we timed the interruptions to occur during particularly cognitively demanding cooking tasks in which the standard kitchen environment could not provide context or progress clues. We focused on situations where the difference of the before and after state of a completed step is hardly discernable (e.g., when accumulating seemingly uniform ingredients such as baking powder and baking soda into the same bowl, adding multiple amounts of the same ingredient into the same bowl, or incorporating ingredients completely into a mixture before proceeding). Thus, we selected these four general cooking actions as strong candidates for problematic interruptions.

- After having added two dry ingredients
- While adding the white sugar
- While adding first dry ingredient
- In between adding multiple eggs

C.3 Cooking Task

In addition to accentuating the effects of the untimely interruptions, we increased the complexity of the cooking task by providing inconvenient cooking utensils and a less than straightforward version of the cookie recipe. First, we rearranged the list of ingredients in alphabetical order instead of the customarily sequential order as directed by the recipe. Next, we limited the measuring units to smaller divisions that the cook had to add multiple amounts of. For example, a $\frac{1}{4}$ cup measure was provided where one or two cups of an ingredient was required, and a $\frac{1}{4}$ teaspoon measure was used where one teaspoon was needed. We provided butter sticks labeled with tablespoon conversions for the cook to compute two-cup amounts instead of allowing them to literally measure out two cups of butter. Lastly, we doubled the yield of the original recipe. As lab subjects tend to focus more attentively on a task than they would in a everyday setting, these modifications to the cooking task help compensate by requiring that the cookie preparation would demand a substantial amount of time and nontrivial amount of attention and working memory to complete.

C.4 Interview Questions

- How did you think you did with your cookie? Poor. OK. Good. Great.
- Did you think you missed a step? No. Perhaps.
- Did you think you repeated a step? No. Yes.
- Which interruption did you find most annoying?
- Which interruption did you find most distracting?
- How did you find it resuming your task? Difficult. Bothersome. Manageable. No problem.
- Did you look at the collage? Never. A few times. Some. Often.
- Did you find the collage helpful? No. Yes.
- Did you find the collage distracting? No. Yes.

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